Précis of Palaeozoic Palaeontology in the Southern Tablelands Region of New South Wales

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This compilation of all known palaeontological data from Lower Ordovician to Upper Devonian rocks exposed in the Boorowa–Crookwell–Taralga–Yass–Goulburn–Braidwood region of southeastern New South Wales, draws on a voluminous scientific literature of more than 270 papers and reports. Within this region are some of the most famous and intensively studied fossiliferous localities in the state, particularly in the Yass–Taemas area. Revised faunal lists provide the basis for new or refined age determinations, resulting in improved biostratigraphic correlation amongst the 64 formations and their members that yield fossils in the region. Early Silurian (early Wenlock) conodonts found in allochthonous limestones of the Hawkins Volcanics, the lowermost unit of the Yass Basin succession, are documented, as are representative conodonts from allochthonous limestone of late Silurian (Ludlow) age previously erroneously assigned to the early Silurian (late Llandovery) Jerrawa Formation. A new species of the coniform conodont *Panderodus* is described under open nomenclature. It is recommended that the name Hanaminno Limestone be suppressed.

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KEYWORDS: Biostratigraphy, Conodonts, Devonian, Graptolites, Ordovician, Palaeontology, Silurian.

INTRODUCTION

Palaeozoic strata exposed in the Boorowa–Crookwell–Taralga–Yass–Goulburn–Braidwood region of southeastern New South Wales (Fig. 1) range in age from Early Ordovician to Late Devonian (Fig. 2) and include, in the Yass–Taemas area, some of the most famous fossiliferous localities in New South Wales. This compilation of all known palaeontological information from these rocks draws on a voluminous scientific literature including more than 270 papers and reports (approximately 15% of which have been published in the *Proceedings of the Linnean Society of New South Wales*) in which Palaeozoic fossils from the region have been documented. The region falls largely within the confines of the Goulburn 1:250,000 and Braidwood 1:100,000 mapsheets that have recently been investigated and remapped by the Geological Survey of NSW (GSNSW), but palaeontological data from adjacent mapsheets is also utilised to provide age constraints. However, unpublished works, such as student theses, are largely excluded to avoid the possibility of introducing nomina nuda or clouding the record with identifications that have not been peer-reviewed. Although some parts of the present paper were incorporated into the Palaeontological Appendix (published on DVD) for the Goulburn Geological Sheet Explanatory Notes (Percival 2012b, in Thomas and Pogson 2012), several identifications and some correlations proposed therein have been revised for this expanded review, which also incorporates previously unpublished data and fossil determinations from the Braidwood region (Fitzherbert in press).

Previous palaeontological studies in the Southern Tablelands region have been concentrated in two highly fossiliferous areas: (1) the Silurian to earliest Devonian succession of the Yass Basin, and (2) the carbonate-dominated Murrumbidgee Group (of Early Devonian age) surrounding Burrinjuck Reservoir. Additional research has focussed on faunas of the

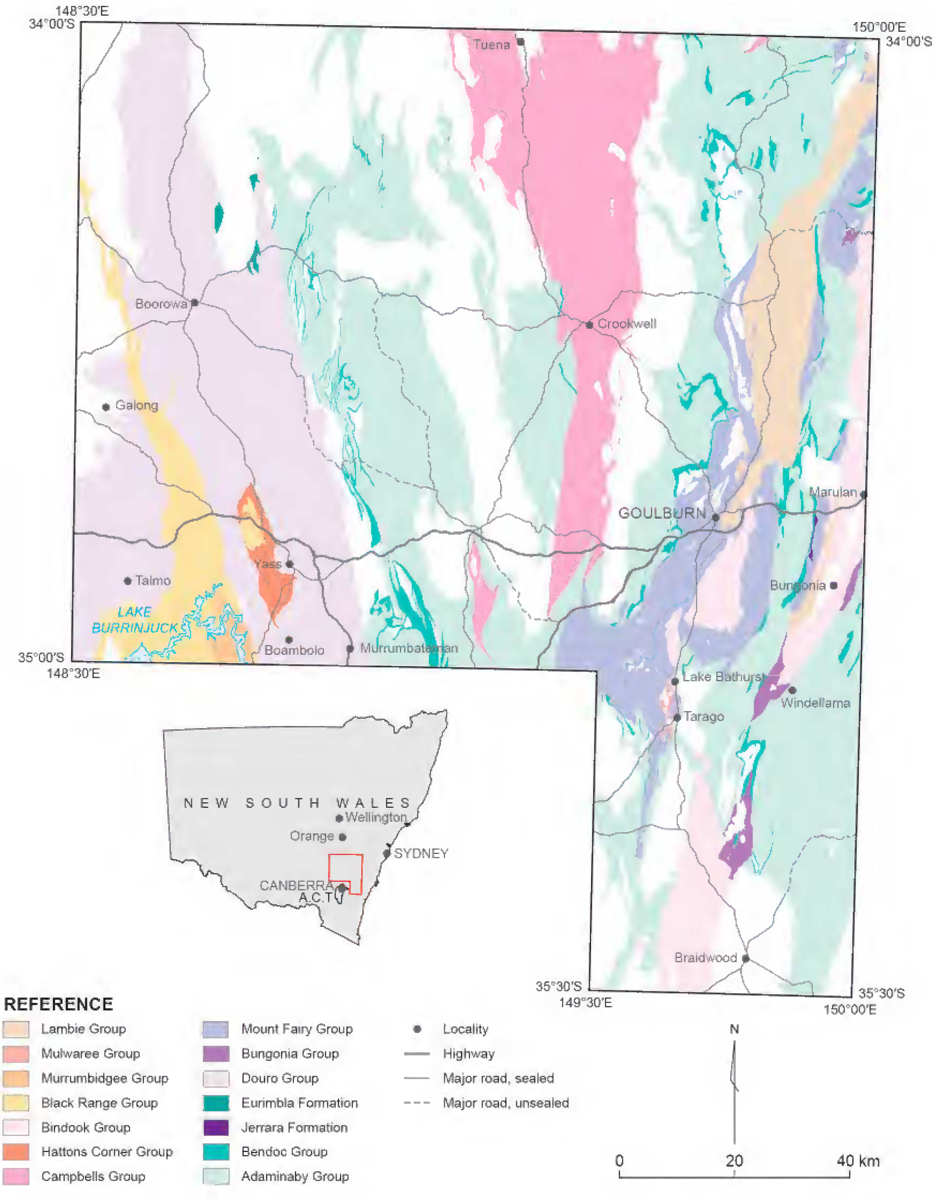


Figure 1. Map of the Southern Tablelands region of southeastern New South Wales, showing the main localities mentioned in the text. Simplified geology, including sedimentary groups referred to in the text, is adapted from the Goulburn 1:250,000 Geological Sheet, Second Edition (Thomas et al. 2013) and the preliminary Second Edition of the Braidwood 1:100,000 Geological Sheet (Fitzherbert et al. 2011). Uncoloured areas are unfossiliferous rocks, predominantly granites.

Early Devonian Windellama Limestone Member of the Tangerang Formation, on Late Ordovician graptolites in the Bendoc Group, and conodont biostratigraphy of cherts in the Early to Middle Ordovician Adaminaby Group.

ORDOVICIAN STRATIGRAPHY AND BIOSTRATIGRAPHY

Adaminaby Group

Abercrombie Formation (θaa on Fig. 2)

The Abercrombie Formation ranges in age from the Early Ordovician (?late Tremadocian to Floian, equivalent to Bendigonian) to the earliest Late Ordovician (Sandbian, or early Gisbornian) (Fig. 2). This latter age is relatively well-constrained, the maximum age less so, with almost all biostratigraphic data being derived from conodonts and other microfauna preserved in cherts (Percival 2012a). Recent mapping of the Abercrombie Formation on the Goulburn 1:250,000 mapsheet has resulted in recognition of several new chert-dominated members (Thomas and Pogson 2012). A summary of the lithostratigraphy of this formation and its constituents is given in Percival et al. (2011).

Unnamed cherts in lowermost Abercrombie Formation

A few very thin and discontinuous chert beds interbedded in a shale-dominated section beneath the Mummel Chert Member are characterised by the presence of *Paracordylodus gracilis* and the absence of *Oepikodus evae*. This suggests an age range for the lowermost Abercrombie Formation of late Tremadoc to early Floian (early Bendigonian).

Mummel Chert Member (θaam on Fig. 2)

Conodonts commonly observed in thick sections of cherts from the Mummel Chert Member include *Oepikodus evae* (often abundant), *Paracordylodus gracilis*, *Periodon flabellum*, *Acodus* sp., *Drepanodus arcuatus*, and other coniform elements probably assignable to *Drepanoistodus*. *Bergstroemognathus extensus* is a rare but distinctive associate, *Microzarkodina* (species indeterminate) is equally uncommon, and one element possibly referrable to *Fahraeusodus marathonensis* was observed. Where *O. evae* is present (e.g. Percival et al. 2003:fig. 1.19, 21-22; Percival et al. 2011:photograph 1; Percival 2012a:fig. 3F), the age of this assemblage could potentially span the range of the eponymous zone, i.e. late Bendigonian (Be3-4) to early Castlemainian (top Ca1). Co-occurrence of *Oepikodus evae* and *Paracordylodus gracilis* restricts the possible age range of some chert horizons to the late Bendigonian (Be3-4). An unusual assemblage identified in one chert sample comprised *Cooperignathus* cf. *C. aranda*, *Prioniodus* sp., and *Periodon flabellum*, together with various coniform elements including *Drepanodus*. Murray and Stewart (2001) incorrectly attributed a Darriwilian-Gisbornian age to this horizon (their locality R16472) on the basis of a mis-identified *Pygodus*.

Remains of sponges preserved in siliceous siltstones grading to spiculites within the Mummel Chert Member are mostly in the form of disaggregated spicules. However, in one sample from the Braidwood mapsheet, two different whole sponges are present. One of these, visible in transverse section across the cylindrical sponge body, shows remarkably well-preserved nail-head spicules characteristic of lithistid demosponges (Percival 2012a:fig. 3L).

Unnamed cherts in middle Abercrombie Formation (θaac on Fig. 2)

Most occurrences of the distinctive conodont *Spinodus spinatus* are in cherts from within the undifferentiated middle part of the Abercrombie Formation (Thomas and Pogson 2012). Typical coniform elements co-occurring in these cherts include *Paroistodus venustus*, *Protopanderodus* sp., *Drepanoistodus* sp. and "*Drepanodus*" sp. Rarer associates include *Periodon macrodentata*?, *Baltoniodus* sp., *Protoprioniodus simplicissimus*, and *Ansella*? sp. Cherts containing this assemblage are most likely of early Darriwilian (Da1?-2) age, although *Spinodus spinatus* has a longer range, extending into the Late Ordovician. For example, in one sample (interpreted to be of Da3 age) from the Goulburn 1:250,000 mapsheet, *S. spinatus* occurs with fragmentary *Histiodella* together with a probable *Paroistodus horridus* element.

Jenkins (1982b) documented a diverse graptolite fauna from black mudstone interbedded with turbiditic sandstone near the crossing of the Kings Highway over the Mongarlowe River, 15 km east of Braidwood. Species recognised include *Didymograptus cognatus*, *Tetragraptus* sp., *Isograptus* sp., *Glossograptus acanthus*, *Glossograptus* sp., *Paraglossograptus* cf. *tentaculatus*, *Apiograptus*? *crudus*, *Cryptograptus inutilis*, *Glyptograptus intersitus*, *Pseudoclimacograptus differtus* and *Diplograptus*? *decoratus*, together with a lingulate brachiopod. Jenkins deduced an age close to the boundary of the Da2 and Da3 zones for this fauna.

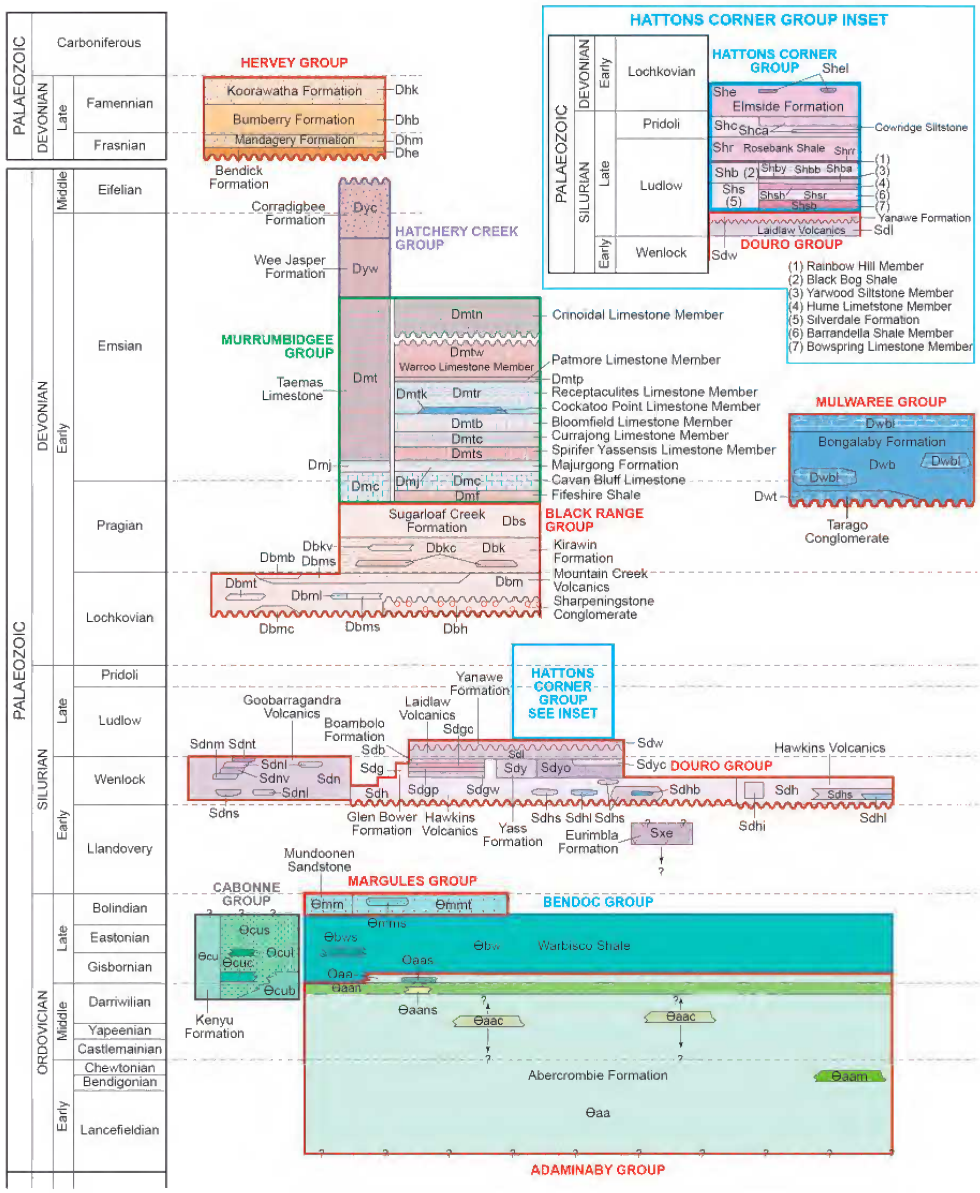
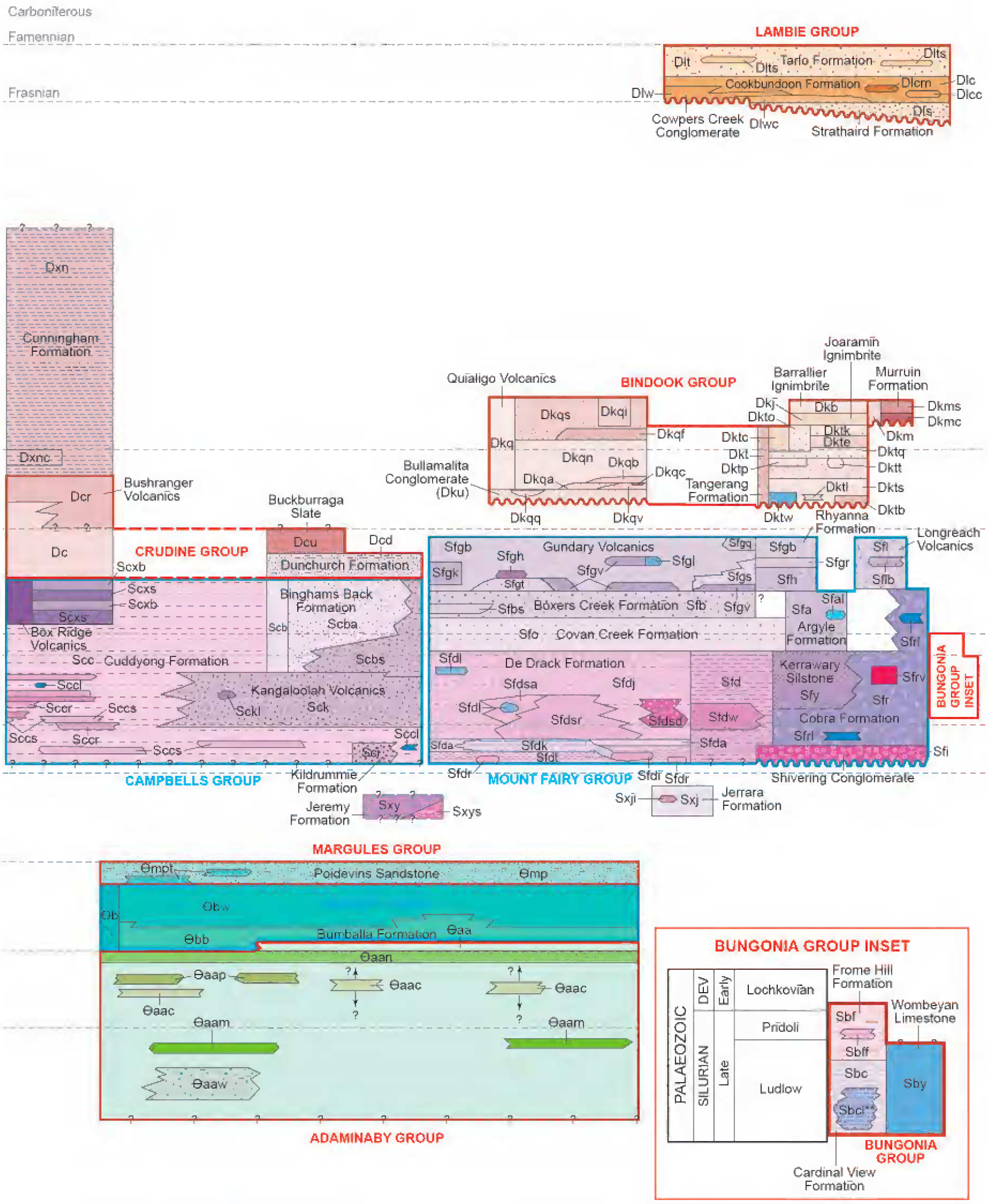


Figure 2 (above and right). Correlation chart for Ordovician, Silurian and Devonian fossiliferous strata (discussed in the text) in the Southern Tablelands region of southeastern New South Wales, mainly adapted from the Time-Space Plot in the Explanatory Notes for the Goulburn 1:250,000 Geological Sheet (Thomas and Pogson 2012), except for Mulwaree Group (modified from Fitzherbert et al. 2011). Units depicted on left side of figure are generally distributed in the western part of the region; those on the facing page are represented in the eastern part of the region. Stratigraphic groups are outlined in solid coloured lines (same colour as their names, in capital letters). Space constraints require many units at formation and member levels to be designated by three- and four-letter codes; for full description of these units refer to Thomas and Pogson (2012).



Peach Tree Chert Member (θaap on Fig. 2)

Murray and Stewart (2001) first identified conodonts including *Cordylodus* (now *Paroistodus*) *horridus* and *Histiodella* sp. from what is now called the Peach Tree Chert Member (their sample R16475) near the junction of Silent Creek and Oaky Creek (approximately 20 km NW of Taralga), and recognised *Periodon aculeatus* in a separate chert band nearby (sample R16476). Resampling of the latter locality (GR 747433 6217083) during the GSNSW Goulburn mapping project yielded *Paroistodus horridus, Periodon macrodentata* and *Histiodella*

sp. (Percival and Sherwin 2005). Those species were depicted by Percival and Zhen (2007:pl. 1, figs 5-9, 16) together with the less common *Baltoniodus* cf. *parvidentatus* and *Nordiora*? sp. Other conodonts recognised in the Peach Tree Chert Member include *Erraticodon* sp., *Multioistodus* sp., *Drepanoistodus*? sp., "*Oistodus*" *tablepointensis*, *Pseudobelodina*? sp., *Protopanderodus* sp. and *Spinodus spinatus*.

Paroistodus horridus locally ranges through most of Darriwilian 3 (although occurrences reported outside Australia rarely extend beyond the upper part of Da2). At least four species of *Histiodella* are known worldwide, and provide the basis for fine-scale subdivision of the Darriwilian from Da1 to the middle of Da3, but these species are extremely difficult to differentiate in chert sections. *Baltoniodus* cf. *parvidentatus* resembles a species typical of the early Darriwilian Kundian stage in Baltoscandia. *Pygodus anitae* (associated with *Paroistodus horridus* and *Histiodella* sp. in a chert from the Silent Creek fire trail on the Taralga 1:100,000 mapsheet) is of middle Darriwilian age (Da3, pre *Pygodus serra* Zone). Overall the age of the Peach Tree Chert Member is interpreted as middle Darriwilian (early-middle Da3).

Nattery Chert Member (θaan on Fig. 2)

Characteristic conodonts found in the Nattery Chert Member are *Periodon aculeatus* and *Pygodus serra* (Percival and Zhen 2007:pl. 1, figs 1-3, 10, 12), *Ansella* sp., *Baltoniodus* sp., together with a variety of generally indeterminate coniform elements. *Microzarkodina* sp. is rarely encountered. Where *P. aculeatus* and *P. serra* co-occur, the potential age of the sample corresponds to the range of *P. serra*, i.e. very late Da3 to the top of Da4. The presence of *P. aculeatus* alone may indicate a late Da3 age, as it slightly precedes the first occurrence of *P. serra*. However, the latter is relatively uncommon, and hence a sample containing just *P. aculeatus* may also be more broadly constrained to the entire range of that species, i.e. late Da3 to early Gisbornian (Gi1) – although this younger limit is somewhat imprecise. Stewart and Fergusson (1995) illustrated a specimen of *Pygodus serra* from the Sunlight Creek Formation (now regarded as Nattery Chert Member) in a cutting on the Bungonia-Goulburn road, where it is associated with *Periodon aculeatus*. Two occurrences of *Pygodus anserinus* were noted in the Nattery Chert Member on the Boorowa 1:100,000 mapsheet; this youngest species of *Pygodus* overlaps with the range of *P. serra* in latest Da4 time and extends into the early Gisbornian (Gi1). Thus all palaeontological evidence consistently points to a maximum age range for the Nattery Chert Member of late Darriwilian (late Da3) to early Gisbornian (Gi1).

Other microfauna observed in thick sections of cherts from the Nattery Chert Member include radiolaria (generally poorly preserved as silica blebs, though occasionally with relic skeletal structure and spines), sponge spicules, and fragmentary acrotretide brachiopods (Percival 2012a).

Uppermost Abercrombie Formation (above Nattery Chert Member)

Graptolites are relatively common in two horizons within the uppermost Abercrombie Formation. Siliceous black siltstones interbedded with, and immediately overlying, the uppermost Nattery Chert Member contain pyritised graptolites, identified by L. Sherwin as *Dicellograptus geniculatus* and *Pseudoclimacograptus* cf. *riddellensis*. These indicate an age range of latest Darriwilian (Da4) to early Gisbornian (Gi1), consistent with the age of the chert. Also present in these siltstones is a trace fossil preserved in epirelief with three straight arms diverging at 120° from a central point (Percival and Sherwin 2004). This trace fossil could not be identified from the literature, and its significance is unknown. Elsewhere in shales in the upper Abercrombie Formation, *Nemagraptus gracilis* has been identified (Percival and Sherwin 2003). This graptolite is the zonal indicator for the early Gisbornian (Gi1) zone but also ranges through the entire Gisbornian stage. Constraints from fossils in underlying and overlying stratigraphic units imply that the most likely age for the top of the Abercrombie Formation is early Gisbornian.

Bendoc Group

Bumballa Formation (θbb on Fig. 2)

Most fossils obtained from the Bumballa Formation are graptolites, but at many localities these are poorly preserved, so identifications and age connotations are not necessarily precise. Typical species present include *Climacograptus bicornis*, *C.* cf. *cruciformis*, *Dicranograptus nicholsoni*, *D.* sp. and *Orthograptus calcaratus* subsp. The most diverse fauna occurs at GR 765682 6165816 and includes *Dicellograptus sextans*, *D.* cf. *divaricatus*, *D.* cf. *intortus*, *Nemagraptus gracilis*, *Reteograptus*? *geinitzianus*, *Pseudoclimacograptus* cf. *scharenbergi* and *Glyptograptus*? sp. (identifications by L. Sherwin). This assemblage, located approximately 320 m above a chert containing Darriwilian conodonts, clearly indicates a Gisbornian age, probably Gi1 (Percival and Sherwin 2004). A graptolite fauna from GR 764830 6216182 on the Taralga 1:100,000 mapsheet

includes several other species whose ranges overlap in the late Gisbornian (Gi2), including *Glossograptus ciliatus*, *Pseudoclimacograptus* sp., dicranograptid fragments and *Corynoides*? sp., associated with lingulate brachiopods and indeterminate caryocaridid arthropods (Percival and Sherwin 2005; Sherwin et al. 2006).

Conodonts found in cherts assigned to the Bumballa Formation at GR 747703 6216870 on the Taralga 1:100,000 mapsheet (Percival and Sherwin 2005) include a pygodiform element of *Pygodus anserinus* (with four clearly-defined rows of nodes), which dates this sample to the *anserinus* Zone (ranging from topmost Da4 to basal Gi1, i.e. straddling the Middle to Late Ordovician boundary). The haddingiform element of *Pygodus* is also present, as well as numerous elements of *Periodon aculeatus*.

Fergusson and Fanning (2002) illustrated trace fossils interpreted as unidentified animal tracks (i.e. grazing trails) on bedding planes at the base of turbidite beds in the Bumballa Formation from the Shoalhaven Gorge, and Jones et al. (1993) reported *Nereites* trace fossils from this area in rocks now attributed to the Bumballa Formation. Both occurrences imply that the ocean floor at the time of deposition of these turbidites was at least partially oxygenated, rather than being anoxic.

<u>Warbisco Shale</u> (θbw on Fig. 2)

Graptolites of Late Ordovician age were first documented from the Goulburn–Marulan–Bungonia region by Naylor (1936), who provided brief descriptions and line drawings of *Orthograptus quadrimucronatus* and *O. calcaratus tenuicornis*. Although not specifically referring to Naylor's paper, VandenBerg and Cooper (1992) examined other specimens attributed to *O. calcaratus tenuicornis* and concluded that its presence in Australasia was doubtful. Sherrard (1943) listed a large number of graptolite species (none of which were described or figured) from localities in the Jerrawa district, east of Yass. She distinguished two horizons, one probably in the latter part of the Gisbornian (from three localities), and the other level (recognised at 30 localities) of definite Eastonian aspect. From the Goulburn–Marulan–Bungonia area, Sherwin (1972) briefly noted the occurrence of conodonts preserved on bedding planes in siliceous shales (now assigned to the Warbisco Shale) with graptolite faunas of Gisbornian and Eastonian ages.

The majority of graptolites identified from the Warbisco Shale on the Goulburn 1:100,000 mapsheet (Percival and Sherwin 2004) and Taralga 1:100,000 mapsheet (Percival and Sherwin 2005) are of Eastonian age. Similar fauna was collected from the Braidwood 1:100,000 mapsheet in the vicinity of Sally Trigonometric Station, about 7.5 km WSW of Tarago (Strusz and Nicoll 1973). The preservation of some specimens does not permit confident recognition of species necessary for precise age determinations, so the following faunal lists only include material that is distinctive or well preserved. The oldest species identified is *Climacograptus tridentatus*, indicative of a late Gisbornian (Gi2) age, from GR 767540 6181065. No species restricted to the earliest Eastonian (Ea1) zone were recognized. One assemblage from GR 765010 6169658 comprises long-ranging species that overlap in Ea2, such as *Dicranograptus nicholsoni*, *D. hians*, *Dicellograptus* sp., *Cryptograptus* cf. *insectiformis*, *Diplacanthograptus spiniferus*, *Orthograptus* cf. *amplexicaulis*, and *O.* ex gr. *pageanus*. Other graptolites of middle to late Eastonian (Ea2-4) age are widespread, including *Dicellograptus* species with the rhabdosome formed into a distinctive figure-8 shape (*D.* cf. *caduceus*), *D. flexuosus*, *D. elegans*, *D.* n. sp. cf. *D. minor*, *D. gravis*, *Orthograptus ruedemanni*?, *Dicranograptus kirki*, *Pseudoclimacograptus*? sp., *Leptograptus eastonensis*, *Ensigraptus caudatus* and *Normalograptus tubuliferus*. Williamson and Rickards (2006) described a similar fauna from weathered black shales now included in the Warbisco Formation at Ryrie Hill, 8 km SSE of Michelago (south of Canberra), to which they assigned an Eastonian 2-3 age, based on the presence of *Leptograptus flaccidus* cf. *macer*, *L.* ?*flaccidus spinifer*, *Dicellograptus morrisi*, *D.* cf. *caduceus*, *Climacograptus* [=*Ensigraptus*] *caudatus*, *C.* [=*Normalograptus*] *tubuliferus*, *C. mohawkensis*, *Orthograptus quadrimucronatus*, *O. calcaratus calcaratus*, *O. c.* ?*priscus*, *O. c.* cf. *vulgatus*, *O. c.* aff. *tenuicornis*, *O. amplexicaulis pauperatus*, *O. a. intermedius* and *Glyptograptus daviesi*. Graptolites found in the Warbisco Shale that are typical of (though not necessarily restricted to) the early Bolindian include *Appendispinograptus longispinus*, *Dicellograptus ornatus*, *D.* cf. *morrisi*, *Euclimacograptus hastatus*, *Leptograptus* sp. or *Pleurograptus* sp., *Orthograptus* cf. *thorsteinssoni* or *O. fastigatus*, *O. quadrimucronatus* and *O.* cf. *amplexicaulis*. The early Bolindian age of this association is confirmed by co-occurrence, e.g. at GR 765732 6151522 and GR 756841 6109803, of *Styracograptus uncinatus*, the zonal indicator species for Bo1 (although this is quite rare). This species was also noted at Ryrie Hill by Williamson and Rickards (2006), possibly from a different level to that yielding the middle Eastonian fauna. Very occasionally, e.g. at GR 758848 6128704, cherty silicified siltstone is present in the Warbisco

Shale. Thin sections prepared of this lithology reveal proximal fragments of graptolites, identified (by L. Sherwin) as *Diplacanthograptus spiniferus* of Eastonian 2-4 age. Conodonts are very rare, generally only represented by simple coniforms, including a possible eobelodiniform element of *Belodina* sp.

Cabonne Group

Kenyu Formation (θcu on Fig. 2)

Percival et al. (2008) documented the conodonts *Belodina compressa*, *Scabbardella* cf. *S. altipes*, *Drepanoistodus suberectus*, *Panderodus gracilis*, *Periodon aculeatus*, *Phragmodus undatus*, *Protopanderodus liripipus*, *Yaoxianognathus wrighti*, and *Yaoxianognathus* sp. from an allochthonous limestone lens (θcul) towards the top of the Kenyu Formation. This fauna indicates a Late Ordovician (late Gisbornian to earliest Eastonian) age for the limestone. Also present in the insoluble residue were the acrotretide brachiopod *Scaphelasma*? sp., the discinide brachiopod *Orbiculoidea* sp., indeterminate large thick-shelled lingulide brachiopods, flat-spired gastropods and hyolithids.

EARLY SILURIAN STRATIGRAPHY AND BIOSTRATIGRAPHY

Eurimbla Formation (Sxe on Fig. 2)

Two samples attributed to this formation (defined by Thomas and Pogson 2012) give conflicting ages (Percival 2001). Thin sections of dark grey-black siltstone, from a small road quarry at GR 662240 6202708 on the Boorowa 1:100,000 mapsheet, contain fragments of graptolites that resemble hair-like species of *Monograptus* s.l. comparable with mid-late Llandoverian forms (L. Sherwin, pers. comm.), together with very well-preserved spinose radiolaria, and a partially disaggregated sponge. This presumably represents the depositional age of the Eurimbla Formation. Another site nearby on the Gunnary Road yields clasts of translucent pale brown-yellow chert in which conodonts (predominantly *Paracordylodus gracilis*, with a few associated *Oepikodus evae*) are abundant and well-preserved. These chert clasts therefore have an age equivalent to the lower part of the *evae* Conodont Zone (Early Ordovician, late Bendigonian to early Chewtonian), and are interpreted as having been reworked into the lower Silurian Eurimbla Formation.

Jerrara Formation (Sxj on Fig. 2)

Naylor (1936) described several species of monograptids from what was then known as the Jerrara Series near Bungonia, and subsequently (Naylor 1939) provided expanded faunal lists from this area. One locality on the Bungonia Road was resampled by Sherwin (1968) who reappraised the fauna, identifying *Streptograptus exiguus* and *Monograptus* cf. *M. nudus*, and assigning a late Llandoverian (*turriculatus* Zone) age.

EARLY SILURIAN TO EARLY DEVONIAN

History of study of Yass Basin fossils

The Silurian to earliest Devonian rock succession in the Yass Basin contains arguably the best known and most intensively studied shallow water shelly faunas of this age in Eastern Australia. Fossil groups that are particularly well represented in the Yass Basin succession include trilobites, brachiopods, corals, conodonts and graptolites; other less conspicuous groups include stromatoporoids, molluscs (bivalves, gastropods, nautiloids), bryozoa, and algae. Relatively precise age constraints (particularly in the upper part of the succession) are provided by conodonts obtained from limestones that are interbedded with siltstones bearing abundant well-preserved graptolitic faunas.

The first documentation of fossils from the "Yass Plains" resulted from their discovery by the explorer Paul de Strzelecki, whose record of his journey in southeastern Australia included a description of a tabulate coral questionably referred to *Favosites gothlandicus* by Lonsdale (1845). Shortly thereafter, W.B. Clarke described the first trilobites from this area (Clarke 1848). Unfortunately, Lonsdale's specimens (though still extant in the Sedgwick Museum at Cambridge University, UK) bear only very generalised locality details, and Clarke's collection – the fossils from which had been described by de Koninck (1876-77, transl. 1898) – was destroyed in the Garden Palace fire in Sydney on September 22, 1882.

An important series of palaeontological investigations in the Yass Basin, particularly concerning trilobites and brachiopods, was undertaken between the 1870s and the early 1920s by Charles Jenkins, A.J. Shearsby, John Mitchell, Robert Etheridge Jr and Felix Ratte. The first three mentioned were self-taught amateur scientists; Robert Etheridge Jr was palaeontologist in the Geological Survey of NSW and subsequently Director of the Australian Museum. W.S. Dun, Etheridge's assistant curator at the Geological Survey (and later palaeontologist there), also participated in several papers. Jenkins (1879) illustrated (without description) several trilobites. Ratte (1887a, 1887b) contributed two papers describing several species. Etheridge and

Mitchell (a local schoolteacher who later was head of Newcastle Technical College) had a productive collaboration describing the trilobite faunas of the Yass region, in a series of six major papers from 1892 to 1917 published in the *Proceedings of the Linnean Society of New South Wales*. Significant later trilobite studies revising and expanding these earlier works are those of Chatterton (1971), Chatterton and Campbell (1980), and Strusz (1980).

Pioneering work on the graptolites of the Yass Basin was carried out by T.S. Hall in 1903, but a detailed study of the faunas throughout the succession was not published for another 34 years. Kathleen Sherrard, initially with assistance from R.A. Keble, described a considerable number of Silurian graptolites, forming the basis for her subsequent recognition of several biostratigraphically significant assemblages (Sherrard and Keble 1937, Brown and Sherrard 1952). Many of the earlier identifications of Sherrard and co-workers have been systematically revised, initially by Jaeger (1967) and subsequently by Rickards and Wright (1999), establishing ties to the global standard graptolite zonation.

Study of the conodont faunas of the Yass Basin was part of a detailed Ph.D mapping project by A.G. Link in the late 1960s and early 1970s. Link (1971) reported initial results, followed by publication of the systematic descriptions of the faunas (Link and Druce 1972). Although based on the form-species concept prevalent at the time (prior to the establishment of multi-element taxonomy), this work was of great significance in establishing a rigorous biostratigraphic framework especially in the upper part of the succession. Subsequent analysis of the faunas (Simpson 1995) has revised the maximum age of the lower formations from Ludlovian to Wenlockian (see discussion later in this paper).

The history of research into Silurian brachiopods of the Yass Basin was recently reviewed by Strusz (2010b). The initial phase of systematic descriptions, commencing with Etheridge (1892b), Dun (1907), Mitchell and Dun (1920), Mitchell (1921, 1923) and Booker (1926), was followed in the 1940s by the studies of Johnston (1941), St Joseph (1942) and Brown (1949) who revised and synonymised several of Mitchell's (1923) species. Commencing in the 1980s, D.L. Strusz published descriptions of the Silurian brachiopods of the Canberra district, also recording identical species from the Yass Basin (Strusz 1984, 1985a). In a series of papers between 2002 and 2010, Strusz completed description and revision of all brachiopods represented in the Yass Basin.

Following the initial documentation of the diverse Silurian coral faunas by Lonsdale (1845) and de Koninck (1876), A.F. Foerste (1888) described a few rugosans (and trilobites) sent to his laboratory in the USA. Other early contributions on the rugosan faunas by R. Etheridge Jr (1881-1894, 1904c, 1913) and A.J. Shearsby (1905, 1906), and subsequently O.A. Jones (1932, 1936), were revised and expanded by Dorothy Hill (1940). Jones (1937) described favositid tabulates and collaborated with Hill to document the heliolitids (Jones and Hill 1940). Pickett and Jell (1974) and McLean (1974, 1976) have systematically revised some of the earlier identifications. Other generic reassignments have been made by Strusz and Munson (1997) for the rugosans, and Munson et al. (2000) for the tabulate corals and chaetetid sponges.

Reinterpretation of the age of the Yass Basin sequence based on conodonts

Link and Druce (1972) recognised four conodont assemblages in rocks of the Yass Basin, the oldest *Neoprioniodus excavatus* fauna succeeded by the *Spathognathodus* sp cf. *ranuliformis*, *Ancoradella ploeckensis–Kockelella variabilis*, and *Belodella triangularis–Polygnathoides siluricus* faunas. They suggested correlations with the conodont zonation of the Carnic Alps (Austria) established by Walliser (1964). Thus the two older Yass Basin faunas were inferred by Link and Druce (1972) to correlate with the Zone of *Ozarkodina crassa*, of early Ludlovian age, although this zonal indicator species was not recognised at Yass. The two younger assemblages contained the zonal indicator conodont species *A. ploeckensis* and *P. siluricus*, respectively, providing precise correlation with international biostratigraphic zonations. Graptolite faunas were consistent with a late Ludlovian to latest Pridolian age for the upper part of the succession, overlying the limestone containing *siluricus* Zone conodonts.

At the time of publication of Link and Druce's research, conodont taxonomy was just commencing a fundamental revolution which would see the elimination of single-element species nomenclature in favour of a multielement apparatus-based species concept. Link and Druce (1972) was also a pioneering work, in that there was no previous local Silurian biostratigraphic zonation using conodonts to correlate with. Link's mapping and stratigraphy was (with some minor revisions in nomenclature) sufficiently rigorous to be widely accepted to the present day. Not until the revision by Simpson (1995) of Australian Silurian biostratigraphy was a reassessment of the Link and Druce conodont faunas undertaken (Table 1).

Table 1 Revised identifications of those conodonts originally described from the Yass Basin using form-species nomenclature by Link and Druce (1972).

[Note: species not italicised in first column have no revised equivalent in second column]
S and C 1998 = Serpagli and Corradini 1998
S and C 1999 = Serpagli and Corradini 1999

Yass Basin conodont identifications of Link and Druce (1972)	Revised and multielement identifications (based on Simpson and Talent 1995)
Acodus curvatus	*Walliserodus curvatus*
Ancoradella ploeckensis	*Ancoradella ploeckensis*
Belodella devonica	*Belodella silurica*
Cordylodus? *dubius*	*Coryssognathus dubius* [Sc element]
Coryssognathus dentatus	*Coryssognathus dubius* [Pa element]
Distomodus curvatus	*Coryssognathus dubius* [Pb, Pc]
Hindeodella equidentata	*Wurmiella excavata*
Icriodus woschmidti	possibly *I. woschmidti hesperius*
Kockelella variabilis	*Kockelella variabilis variabilis* & *K. variabilis ichnusae* S and C 1998
Ligonodina elegans	*Oulodus elegans*
Ligonodina salopia	*Kockelella variabilis* [Sc element]
Ligonodina silurica	*Kockelella variabilis*
Lonchodina detorta	
Lonchodina greilingi	*Kockelella variabilis* [Sb element]
Lonchodina walliseri	*Pseudolonchodina fluegeli*? or
	Oulodus elegans
Neoprioniodus bicurvatoides	
Neoprioniodus bicurvatus	*Ozarkodina confluens*
Neoprioniodus excavatus	*Wurmiella excavata*
Neoprioniodus latidentatus	
Neoprioniodus multiformis	*Ancoradella ploeckensis* [M element]? or
	Kockelella variabilis [M element]
Oneotodus? *beckmanni*	*Pseudooneotodus beckmanni*
Ozarkodina crassa	
Ozarkodina denckmanni	
Ozarkodina gaertneri	*Ancoradella ploeckensis* [Pb element]?
Ozarkodina media	*Wurmiella excavata*
Ozarkodina ortus	
Ozarkodina typica	*Ozarkodina confluens*
Ozarkodina ziegleri aequalis	
Ozarkodina cf. O. ziegleri tenuiramea	
Ozarkodina cf. *O. ziegleri ziegleri*	*Kockelella variabilis* [Pb element]
Ozarkodina sp.	
Panderodus gracilis	*Panderodus unicostatus*
Panderodus panderi	*Panderodus recurvatus*
Panderodus simplex	*Panderodus unicostatus*
Panderodus unicostatus serratus	*Panderodus serratus*
Panderodus unicostatus unicostatus	*Panderodus unicostatus*
Plectospathodus extensus s.l.	*Wurmiella excavata*
Plectospathodus extensus lacertosus	
Plectospathodus flexuosus	*Ozarkodina confluens*
Polygnathoides emarginatus	
Polygnathoides siluricus	*Polygnathoides siluricus*
Scolopodus diplicatus	
Spathognathodus fundamentatus	*Kockelella absidata sardoa* S and C 1999
Spathognathodus inclinatus inclinatus	*Wurmiella excavata*
Spathognathodus primus	*Ozarkodina confluens*
Spathognathodus cf. *S. ranuliformis*	*Kockelella ranuliformis*
Spathognathodus remscheidensis	*Zieglerodina remscheidensis*
S. cf. *S. steinhornensis eosteinhornensis*	*Oz. remscheidensis eosteinhornensis*
Synprioniodina silurica	*Ancoradella ploeckensis* [M element]?
Trichonodella excavata	*Wurmiella excavata*
Trichonodella inconstans	*Kockelella variabilis* [Sa element]
Trichonodella symmetrica	*Ozarkodina confluens*
Trichonodella trichonodelloides	*Aspelundia*? *fluegeli*

Wurmiella excavata (Branson and Mehl, 1933), previously known as *Ozarkodina excavata*, and recognised by Link and Druce (1972) as the form species *Neoprioniodus excavatus*, dominates the oldest assemblage. This is a prolific, easily recognised and long ranging multielement species distributed world-wide in the Silurian and Early Devonian. Although long presumed to occur no earlier than the late Wenlockian, it is now widely identified in strata of Telychian (late Llandoverian) age. Link and Druce identified a few specimens of *W. excavata* in the Cliftonwood Limestone Member (of the Yass Formation) and the lower part of the Euralie Limestone Member (now assigned to the Yanawe Formation). Additional material of *W. excavata* was found in allochthonous limestones in the older Hawkins Volcanics (Fig. 3c-g) as a result of sampling undertaken during the Goulburn mapping program by the GSNSW (Thomas and Pogson 2012). However, due to its extended range, *W. excavata* is of no use as a zonal indicator, and other species must be sought to constrain the age of inception of deposition in the Yass Basin.

The characteristic form of the second of Link and Druce's conodont faunas, *Spathognathodus* sp. cf. *S. ranuliformis*, is compared with a species which is more restricted stratigraphically than *W. excavata*. Now referred to in multi-element nomenclature as *Kockelella ranuliformis* (Walliser, 1964), this species typically occurs in the eponymous *ranuliformis* Zone of lower to mid-Sheinwoodian age, but first appears in the underlying *Pterospathodus amorphognathoides* Zone (late Telychian to earliest Sheinwoodian) that spans the Llandovery–Wenlock boundary. Its local upper limit was placed by Bischoff (1987) within the *K. amsdeni* to *K. variabilis* zones (late Sheinwoodian to mid-Homerian, or about mid-Wenlockian). In a detailed evaluation of lineages in *Kockelella* species, Serpagli and Corradini (1999) came to a similar conclusion, noting the first appearance of *K. ranuliformis* in the mid-Telychian *Pterospathodus celloni* Zone, and placing its last appearance near the top of the *Ozarkodina sagitta rhenana* Zone, in the latest Sheinwoodian. Previously published Australian records of *K. ranuliformis* occurring in mid-Ludlow strata (base of *siluricus* Zone – cf. Link and Druce 1972, Simpson et al. 1993, Simpson and Talent 1995) are probably incorrect, and refer to aberrant specimens of the somewhat similar species *Ozarkodina crispa* (A. Simpson pers. comm. May 2006). There is some uncertainty in the identification (apparent from the cf.) of the Link and Druce species from Yass, but Simpson (1995) believed this corresponded to a late form of *K. ranuliformis*. Hence the age of the Euralie Limestone Member of the Yanawe Formation (immediately below the Silverdale Formation) that contains this second conodont fauna is most likely no younger than mid-Wenlockian, not mid-Ludlovian as shown by Simpson (1995: text-fig. 2). We have now identified *K. ranuliformis* in allochthonous limestone blocks in the Hawkins Volcanics, towards the base of the Yass Basin succession (Fig. 3a-b).

This reassessment has significant age connotations for older units of the Yass Basin succession beneath the Yanawe Formation. The Hawkins Volcanics (in which *K. ranuliformis* is known to occur), Yass Formation and Laidlaw Volcanics most likely range in age from early to mid-Wenlockian (early Sheinwoodian to mid Homerian). The Yanawe Formation and the lower half of the Silverdale Formation, up to the middle of the Bowspring Limestone Member, probably span the mid-Wenlockian to early Ludlovian (mid Homerian to late Gorstian) interval. Units assigned to the *A. ploeckensis* Zone, of latest Gorstian to early Ludfordian age, include the upper Bowspring Limestone Member, the *Barrandella* Shale Member and lower Hume Limestone Member of the Silverdale Formation. The *P. siluricus* Zone extends through the upper Hume Limestone Member, lower Black Bog Shale and Yarwood Siltstone Member. Age dating of the overlying Yass Basin succession (upper Black Bog Shale, Rosebank Shale, and Cowridge Siltstone) is well-constrained by late Ludlovian and Pridolian graptolites. Our current knowledge of Yass Basin biostratigraphy, summarised in Strusz (2010b: fig. 1), demonstrates that this re-evaluation of the age, particularly of the oldest units, has doubled the estimated duration of sedimentation in the Yass Basin from about 5 Ma (at the time of Link and Druce's study) to approximately 10 Ma.

Douro Group

Goobarragandra Volcanics (Sdn on Fig. 2)

Isolated limestone pods (Sdnl) occurring within the Goobarragandra Volcanics in the Talmo–Galong district have been assigned a Silurian (most likely Wenlockian – Ludlovian) age on the basis of macrofauna, identified by Sherwin (1968) as including the corals *Aphyllum lonsdalei*, *Tryplasma* sp., *Heliolites daintreei*, halysitids (possibly *Acanthohalysites australis*), *Striatopora* sp. and pentamerid brachiopods (cf. *Kirkidium*). Attempts to increase the precision of this age determination during GSNSW mapping of the Yass 1:100,000 sheet were unsuccessful as conodont yields were extremely low, with only non-diagnostic coniform elements (*Panderodus gibber*?, and *Panderodus unicostatus* or *P. gracilis*) and one valve of the lingulide brachiopod *Paterula* sp. being recovered.

Figure 3. **a-b, *Kockelella ranuliformis* (Walliser, 1964) from sample C2045, a, Pa element, MMMC5071, upper view (IY312-001); b, Pb element, MMMC5072, inner-lateral view (IY312-002). c-g, *Wurmiella excavata* (Branson and Mehl, 1933); c, Pb element, MMMC5073, from sample C2045, inner-lateral view (IY312-003); d-e, Pa elements from sample C2063, d, MMMC5074, outer-lateral view (IY312-004), e, MMMC5075, inner-lateral view (IY312-006); f, Sa element, MMMC5076, from sample C2063, upper-posterior view (IY312-005); g, Sc element, MMMC5077, from sample C2051, inner-lateral view (IY312-013). h-l, *Panderodus greenlandensis* Armstrong, 1990. h, Sd element, MMMC5078, from sample C2063, outer-lateral view (IY312-010); i, Sc element, MMMC5079, from sample C1859, outer-lateral view (IY312-015); j, Sa element, MMMC5080, from sample C2051, posterior view (IY312-016); k, P element, MMMC5081, from sample C2063, outer-lateral view (IY312-011); l, Sb element, MMMC5082, from sample C2051, outer-lateral view (IY312-017). m-n, *Panderodus* sp. A of Wang and Aldridge, 2010; m, falciform element, MMMC5083, from sample C2025, outer-lateral view (IY312-014); n, MMMC5084, from sample C2051, outer-lateral view (IY312-018). o, *Panderodus panderi* (Stauffer, 1940); falciform element, MMMC5085, from sample C2063, outer-lateral view (IY312-007). All from limestone blocks in the Hawkins Volcanics. Scale bar 100 µm.**

Hawkins Volcanics (Sdh, Sdhl, Sdhs on Fig. 2)

Sherwin and Strusz (2002) re-evaluated a graptolite specimen found in mudstones within the lower Hawkins Volcanics, determining it to be *Pristiograptus* ex. gr. *meneghini*. A comparable species *Pristiograptus* sp. cf. *P. meneghini*, described by Rickards et al. (1995) from the lower Panuara Formation in the Quarry Creek district, west of Orange, was assigned an age of “middle Wenlock, possibly in the range of *rigidus* to *linnarssoni* (=*flexilis*) zones” equating to the middle to upper Sheinwoodian. The age of the top of the Hawkins Volcanics is constrained by conodonts from the Euralie Limestone Member (of the overlying Yanawe Formation) that are most likely to be no younger than latest Sheinwoodian, or mid-Wenlockian (see preceding discussion on age of the Yass Basin sequence).

Biostratigraphically significant conodonts were recovered from several limestone blocks in the lower Hawkins Volcanics during GSNSW mapping of the Boorowa and Gunning 1:100,000 mapsheets. Most useful of these are *Kockelella ranuliformis* (Fig. 3a-b) which extends from the *Pterospathodus celloni* conodont Zone (late Llandoverian) through its eponymous Zone to the succeeding *Ozarkodina sagitta rhenana* conodont Zone (early Wenlockian) in Europe and Greenland (Serpagli and Corradini 1999), and *Panderodus greenlandensis* Armstrong, 1990 (Fig. 3h-l) which in the Boree Creek area (near Orange) ranges from the uppermost *Pterospathodus amorphognathoides* Zone into the lower part of the succeeding *K. ranuliformis* Zone in the early Wenlockian (Cockle 1999). Although these two species do not co-occur in any of the samples examined, the overlap in their ranges in the early Wenlockian supports this as the maximum age of the lower Hawkins Volcanics. Long ranging conodonts identified in limestones within the Hawkins Volcanics on the Boorowa mapsheet (Percival 2001) include *Wurmiella excavata* (Fig. 3c-g) and other species of *Panderodus* (Fig. 3m-o).

Macrofossils from conodont sample C1858 on the Boorowa mapsheet (Percival 2001) include the tabulate coral *Cladopora seriatopora*, together with a new species of the stromatoporoid *Labechia* and large indeterminate strophomenide brachiopods. Occurring with *Panderodus greenlandensis* on the Gunning mapsheet (Percival and Sherwin 2003) are macrofossils including pentameride brachiopods (possibly *Kirkidium*) and a large solitary rugose coral.

The Hanaminno Limestone, a unit of very limited extent on the Boorowa 1:100,000 mapsheet (exposed in a creek east of Meringullalong locality at GR 668080 6193016, about 11 km NE of Boorowa and 13.5 km south of Frogmore), was formally defined in Thomas and Pogson (2012) on the basis of a single well-preserved Pa element attributed to the conodont *Astropentagnathus irregularis* Mostler, 1967, recovered from the residue of GSNSW conodont sample C1862 (Percival 2001). This identification supported a late Llandovery age for this limestone, distinguishing it from allochthonous limestone blocks (containing an early to middle Wenlock conodont fauna) assigned to the Hawkins Volcanics which are exposed in the nearby vicinity, although stratigraphic relationships in the area are obscured by alluvial deposits. However, both the original identification and the age inference were incorrect, and this conodont (Fig. 4a-b) is now regarded as a Pa element of *Kockelella*, most likely close to *K. variabilis* Walliser, 1957 (Peep Männik, pers. comm. 2016). In the sample it was associated with three elements of *Panderodus* sp. nov. (Fig. 6a). These conodonts are described in the Appendix to the present paper.

The age implied by the presence of *K.* cf. *K. variabilis* is certainly no older than Wenlock, possibly similar to that of the fauna in the Hawkins Volcanics, and removes the rationale of naming the Hanaminno Limestone as a separate, older, stratigraphic unit. We therefore recommend that further usage of this name be abandoned.

Sherrard (1952) described the gastropods *Euomphalopterus* cf. *E. alatus subundulatus* and *Temnospira monilis*, together with a new species of bivalve *Cosmogoniophora sinuosa*, from a locality known as “Vallance’s Hill”, about 2.5 km due east of the village of Murrumbateman, and from near Nanima Trig on strike approximately 3 km southeast, in sandstone within an area now mapped as Hawkins Volcanics. These shells (identifications of which are in need of revision) are associated with a brachiopod referred to *Howellella* cf. *elegans*, and a fragmentary echinoid (Philip 1963).

Bango Limestone Member (Sdhb on Fig. 2)

Common on weathered surfaces in the Bango Quarry is a halysitid coral that Brown (1941) identified as *Acanthohalysites pycnoblastoides*. However, Byrnes (in Pickett 1982) considered it closer to a species group now synonymised with *Falscicatenipora chillagoensis*. Pervasive recrystallisation of the limestone hinders a precise species determination. The tabulate coral fauna is assigned to the Dripstone Assemblage of Wenlockian to basal Ludlovian age (Munson et al. 2000). Conodont yields from the recrystallised limestone are extremely low, with only non-diagnostic coniform elements recovered.

<u>Glen Bower Formation</u> (Sdg, Sdgc on Fig. 2)

Rugose corals from the Glen Bower Formation, described by Hill (1940), include *Hercophyllum shearsbyi* – now *Phaulactis shearsbyi* – and *Entelophyllum latum*. Tabulate corals listed by Munson et al. (2000) as occurring in the Glen Bower Formation (based on an unpublished study by Byrnes 1972) include *Desmidopora multitabulata*, *D.* sp., *Laceripora* sp., *Favosites allani*, *F. gothlandicus*, *F. lichenaroides*, *F. regularis*, *F. yassensis*, *Cladopora seriatopora*, *Parastriatopora coreanica*, *Pseudoplasmopora heliolitoides*, *Propora conferta*, *Heliolites daintreei*, *Coenites juniperinus*, *C. pinaxoides*, *Alveolites* spp, *Syringopora* spp, and *Syringoporinus* cf. *tonkinensis*. These forms are typical of the Hattons Corner Assemblage, as interpreted by Strusz and Munson (1997) and Munson et al. (2000), who correlated the Glen Bower Formation with the Cliftonwood Limestone Member of the Yass Basin.

In redescribing the brachiopod *Atrypoidea* (*Atrypoidea*) *australis*, Strusz (2007a) illustrated one specimen from the Glen Bower Formation at Glenbower, and listed several others in the Australian Museum collection that had been obtained in the Boambolo area, southeast of Yass.

Nautiloids *Actinoceras* and *Ormoceras* have been recognized in this formation by Teichert and Glenister (1952) but remain undescribed. From probable Glen Bower Formation at Forest Creek in the Boambolo district, Sherrard (1960) recorded the bivalves *Cyrtodonta lissa*, *Grammysia compressa*, *Paracyclas orbiculata*, *Grammysioidea declivis* and *Goniophora* sp.

Conodonts identified from the middle part of the Glen Bower Formation were reported by Feary (1986) as *Ozarkodina excavata* (now *Wurmiella excavata*), *Panderodus* sp. and a single element of *Pelekysgnathus dubius* (now *Coryssognathus dubius*). These species occur in what Feary (1986) termed the upper Glen Bower Formation (equating to the Connell Member of the current terminology – Thomas and Pogson 2012) together with *Kockelella ranuliformis*. As discussed earlier, *K. ranuliformis* first appears locally in the *Pterospathodus amorphognathoides* Zone (late Telychian to earliest Sheinwoodian) and according to Bischoff (1987) it ranges into the *K. amsdeni* to *K. variabilis* zones (late Sheinwoodian, or early Wenlockian), although Serpagli and Corradini (1999) record its last appearance in European successions as near the top of the *Ozarkodina sagitta rhenana* Zone (latest Sheinwoodian). Hence the Connell Member is most likely no younger than early Wenlockian (latest Sheinwoodian) in age.

<u>Yass Formation</u> (Sdy on Fig. 2)

Most fossils described from the Yass Formation have come from the Cliftonwood Limestone Member (see below). The fauna listed here is from the undifferentiated Yass Formation.

Strusz (1984, 2005a, 2007a, 2009, 2010a) described the brachiopods *Atrypa* (*Atrypa*) cf. *A. dzwinogrodensis*, *Atrypina* (*Atrypina*) cf. *A. latesinuata*, *Atrypoidea* (*Atrypoidea*) *australis*, *Agarhyncha australe*, *Hedeina bruntoni*, *Spirinella caecistriata* and *Tuvaerhynchus*? sp. from the Yass Formation. The '*Striispirifer*'–*Spirinella* Community to which this fauna was assigned by Strusz and Garratt (1999) should now be referred to as the *Hedeina*–*Spirinella* Community; according to their interpretation this fauna inhabited subtidal (to locally intertidal) depths generally consistent with Benthic Assemblage (BA) 3.

Bivalves described by Sherrard (1960) from the "Yass Series at Yass" include *Rhombopteria laminosa*, *Orthonota* sp., *Ctenodonta* (*Tancrediopsis*) *victoriae*, *Grammysia compressa*, *Actinopterella minuta*, *A. formosa*, *Paracyclas orbiculata*, and *Goniophora* sp.

<u>Cliftonwood Limestone Member</u> (Sdyc on Fig. 2)

Brachiopods (*Spirinella caecistriata*) from this unit were first described by Johnston (1941). Strusz (1985b, 2002, 2003, 2007a, 2007b, 2010a) described the entire brachiopod fauna, including *Atrypina* (*Atrypina*) cf. *A. latesinuata*, *Spirigerina mitchelli*, *Coelospira cavata*, *Navispira*? *bicarinata*, *Epelidoaegiria minuta chilidifera*, *Morinorhynchus shearsbyi*, and *Salopina mediocostata*.

McLean (1976) listed rugose corals from the Cliftonwood Limestone Member as *Phaulactis shearsbyi*, *Holmophyllum multiseptatum*, *Rhizophyllum interpunctatum* and *R. robustum*. Tabulate corals recorded by Munson et al. (2000) include *Heliolites* sp., *Alveolites piriformalis*, *A.* sp., *Coenites pinaxoides*, *Syringopora* sp. and *Aulopora* sp.

Chapman (1909) described the ostracod *Leperditia shearsbii* from this unit.

<u>Yanawe Formation</u> (Sdw on Fig. 2)

Rugose corals recorded from the Euralie Limestone Member of the Yanawe Formation by McLean (1976) are *Phaulactis shearsbyi* and *Tryplasma lonsdalei* [now assigned to *Aphyllum*]. *Heliolites* sp. is the only tabulate coral recognised in this unit, according to Munson et al. (2000). Link and Druce (1972) noted the presence of the stromatoporoids *Anostylostroma*, *Intexodictyon*, *Clathrodictyon*,

Hermatostroma and *Stromatopora typica*, none of which have been described or illustrated from this level.

Link and Druce (1972) also list several species of corals as occurring in the overlying Gums Road Limestone Member of the Yanawe Formation, although again only *Heliolites* sp. was recorded from this unit by Munson et al. (2000) in their survey of all tabulate coral species present in the Silurian of Australia.

Hattons Corner Group

Silverdale Formation (Shs on Fig. 2)

The *Ancoradella ploeckensis* conodont Zone spans the upper Bowspring Limestone Member, the Barrandella Shale Member and the lower Hume Limestone Member (Link and Druce 1972), indicating a latest Gorstian to early Ludfordian age for much of the Silverdale Formation (using the timescale of Strusz 2007c). The upper Hume Limestone Member contains conodonts of the ensuing *Polygnathoides siluricus* Zone, of mid to late Ludfordian age (late Ludlovian).

The dendroid graptoloid *Dictyonema delicatulum barnbyensis*, described from the Silverdale Formation by Rickards and Wright (1999), is otherwise known only from the Barnby Hills Shale near Neurea (SSW of Wellington in central west NSW), where it is associated with a late Ludlovian (*inexpectatus*/*kozlowskii* zones) graptolite assemblage (Rickards and Wright 1997).

Brachiopods from the Silverdale Formation described by Strusz (2002, 2003, 2007a, 2007b, 2010a) include *Atrypa* (*Atrypa*) cf. *A. dzwinogrodensis*, *Atrypoidea* (*Atrypoidea*) *australis*, *Dolerorthis exatripalude*, *Mesoleptostrophia* (*Mesoleptostrophia*) *quadrata* and *Morinorhynchus oepiki* [the latter two species restricted to the basal part of the formation], *Spirinella caecistriata*, *Nanattegia yassensis*, and possibly *Navispira*? *bicarinata*.

Bowspring Limestone Member (Shsb on Fig. 2)

Conodonts of the *Ancoradella ploeckensis* Zone make their initial appearance in the upper part of the Bowspring Limestone Member (Link and Druce 1972), indicating a latest Gorstian (early Ludlovian) age for this level.

The brachiopod fauna of the Bowspring Limestone Member is not as diverse as in other more shaly units of the Yass Basin succession, but one particularly distinctive form – the large pentameride *Aliconchidium yassi*, described by St Joseph (1942) and Boucot et al. (1969) – is restricted to this limestone member. Other brachiopods (described by Strusz 2005b, 2007a, 2010a) include *Atrypa* (*Atrypa*) cf. *A. dzwinogrodensis*, *Spirinella caecistriata* and *Conchidium* cf. *C. hospes*. The presence of large pentamerides in the Bowspring Limestone Member (and their absence from the remainder of the Yass Basin succession) supports assignment of this fauna to the Pentamerinid Community that was characteristic of a rough water BA3 environment (Strusz and Garratt 1999).

Birkhead (1978) described stromatoporoids from the Bowspring Limestone Member including *Anostylostroma conjugatum*, *A. furcatum*, *Intexodictyon* cf. *I. perplexum*, *Parallelostroma maestermyrense*, and the new species *Plexodicyon hattonense*. An attungaiid sponge (unnamed new genus and species, known from only one specimen) was described by Pickett (1969) from this level at Silverdale.

Following the important contribution by Hill (1940) describing the rugose coral fauna, McLean (1974) redescribed *Yassia enormis*, and McLean (1976) listed all rugose corals known from the Bowspring Limestone Member, including *Phaulactis shearsbyi*, *Entelophyllum yassense*, *Zelolasma*? *praecox*, *Toquimaphyllum spongophylloides*, *T.*? *shearsbii*, *Yassia enormis*, *Stylopleura liliiformis*, *Pycnostylus dendroides*, *Aphyllum lonsdalei*, *Cystiphyllum* sp. cf. *bohemicum*, and *Holmophyllum colligatum*.

Favositid tabulate corals described (by Walkom 1912, and Jones 1937) from the Bowspring Limestone Member at Hattons Corner include *Favosites gothlandicus*, *F. triporus*, *F. richardsi*, *F. regularis*, *F. libratus* and possibly *F. allani*. The heliolitid fauna (Dun 1927; revised by Jones and Hill 1940) comprises *Heliolites daintreei*, *H.* sp., *Pseudoplasmopora heliolitoides*, and *Propora conferta*. *Coenites* sp. is also present. These species lists include synonymies noted by Munson et al. (2000:54).

Barrandella Shale Member (Shsr on Fig. 2)

Strusz (2002, 2003, 2005b, 2007a, 2007b, 2009, 2010a) completely revised the brachiopod fauna of the Barrandella Shale Member and documented several new species; forms described include *Atrypa* (*Atrypa*) cf. *A. dzwinogrodensis*, *Atrypoidea* (*Atrypoidea*) *australis*, *Nucleospira paula*, *Ascanigypa glabra*, *Barrandina wilkinsoni*, *Clorinda minor*, *Dolerorthis exatripalude*, ambocoeliinae? gen. et sp. indet., *Endospirifer anxius*, *Nanattegia yassensis*, *Salopina mediocostata*, *Leptaena compitalis*, *Mesopholidostrophia bendeninensis*, *Epelidoaegiria minuta chilidifera*, *Morinorhynchus oepiki* and *Tuvaerhynchus*? sp.

Tabulate corals described or recorded from this unit (by Walkom 1912; Etheridge 1921; Jones 1927, 1937; Jones and Hill 1940), at Hattons Corner on the Yass River, include *Favosites gothlandicus*, *F. triporus*, *F. richardsi*, *F. regularis*, *F. libratus* and *F. allani*, *Hattonia etheridgei* (redescribed by Pickett and Jell 1974), *Heliolites daintreei*, *Alveolites piriformalis*, *Alveolites* sp., *Coenites* sp., *Syringopora* sp. and *Aulopora* sp.

The Barrandella Shale Member contains the greatest diversity of rugose corals in the Yass Basin succession, most of which were described by Etheridge (1890a, 1891, 1894, 1907) and Hill (1940). Species listed by McLean (1976) as occurring in this unit [with generic reassignments following Munson et al. (2000)], include *Entelophyllum yassense*, *Idiophyllum patulum*, *Zelolasma*? *praecox* (redescribed by McLean 1976), *Phaulactis shearsbyi*, *Toquimaphyllum spongophylloides*, *T.*? *shearsbii*, *Stylopleura liliiformis*, *Mucophyllum crateroides*, *Pycnostylus congregationis*, *P. dendroides*, *Aphyllum lonsdalei*, *A. delicatulum*, *Tryplasma derrengullenense*, *Cystiphyllum* sp., *Rhizophyllum interpunctatum*, *R. yassense*, and *R. brachiatum* (described by McLean 1976).

Etheridge (1897) described the only known example of a polyplacophoran (chiton) in the Silurian of NSW, that he named *Chelodes calceoloides*, from this level. The type specimens of *C. calceoloides* were refigured by Hoare and Farrell (2004). The nautiloid *Ophioceras giblini* described by Chapman (1934) probably comes from the Barrandella Shale Member, according to Strusz (1996:104).

Bryozoa documented from this unit include the new species *Penniretepora lobata* and *Pesnastylus humei* of Crockford (1941), and *Fenestella yassensis* and *Heterotrypa humensis* described by Ross (1961).

The crinoids *Lecanocrinus breviarticulatus*, described by Chapman (1934), and *Pisocrinus yassensis*, described by Etheridge (1904b), also occur in this member. Unfortunately, the type material of both taxa was unable to be located for this review.

Strusz and Garratt (1999) selected the fauna of the Barrandella Shale Member to represent their *Barrandina–Atrypoidea–Spirinella* Community that lived in a moderately deep water BA3-4 environment.

<u>Hume Limestone Member</u> (Shsh on Fig. 2)

The fauna of the Hume Limestone Member is dominated by framework-building organisms such as corals, stromatoporoids and sponges, representative of the widespread *Favosites*–massive stromatoporoid Community that inhabited high energy environments in tidal to high subtidal water depths of Benthic Assemblages 2-3, most likely BA3 (Strusz and Garratt 1999). Tabulate corals described from this unit include *Favosites regularis*, heliolitids (documented by Dun 1927 and revised by Jones and Hill 1940) including *Pseudoplasmopora heliolitoides*, *Propora conferta*, *Heliolites daintreei* and *Heliolites* sp., and the alveolitines *Alveolites piriformalis*, *Alveolites* sp. and *Coenites* sp.; *Hattonia etheridgei* illustrated by Picket and Jell (1974) probably came from this level. Hill (1940) documented the rugose coral fauna, though many of these species have subsequently been reassigned to other genera (see Strusz and Munson 1997). Rugose corals listed by McLean (1976) [generic attributions revised by Munson et al. 2000] include *Phaulactis shearsbyi*, *Entelophyllum yassense*, *Idiophyllum patulum*, *Zenophila walli*, *Toquimaphyllum spongophylloides*, *Mucophyllum crateroides*, and *Aphyllum lonsdalei*.

The stromatoporoid fauna described by Birkhead (1976) from the Hume Limestone Member includes *Plumatalinia balticivaga*, *P. densa*, *Rosenella dentata*, *Clathrodictyon delicatulum*, *C. tenuis*, *Actinodictyon keelei*, *Picnodictyon densum*, *Diplostroma yavorskyi*, *Schistodictyon conjugatum*, and *Parallelostroma maestermyrense*. Pickett (1969) described the sponge *Astylospongia radiata* from shales immediately above the Hume Limestone Member at Hattons Corner, although the exact stratigraphic horizon is uncertain.

Bryozoa from either this unit or the underlying Barrandella Shale Member include *Cheilotrypa* sp. A, described by Ross (1961), and an undescribed *Fistulipora*.

Brachiopods are rare in the Hume Limestone Member, relative to the remainder of the Yass Basin succession; only *Reticulatrypa pulchra*, redescribed by Strusz (2007a), possibly comes from this level – though that record is based on a locality description provided by Mitchell and Dun (1920) in the original description and has not been able to be corroborated. This species is certainly common in the overlying Black Bog Shale.

Tentaculites ornatus, described by Sherrard (1967) from limestone at Hattons Corner, comes from the Hume Limestone Member.

<u>Black Bog Shale</u> (Shb on Fig. 2)

Brachiopods are abundant and diverse within the Black Bog Shale. Many of the species listed here, described or revised by Strusz (2002, 2003, 2007a, 2007b, 2009, 2010a), are also present in the Yarwood Siltstone Member but some are confined to levels in the Black Bog Shale below that unit. The fauna includes *Atrypa* (*Atrypa*) cf.

A. dzwinogrodensis [possibly present in the basal few metres of this unit], *Reticulatrypa pulchra*, *Atrypina* (*Atrypina*) cf. *A. latesinuata*, *Gracianella* (*Gracianella*) *kausi yassensis*, *Spirinella caecistriata*, *Spirigerina mitchelli*, *Atrypoidea* (*Atrypoidea*) *australis*, *Nucleospira paula*, *Coelospira cavata*, *Leptaena compitalis*, *Desistrophia papilio*, *Mesopholidostrophia bendeninensis*, *Endospirifer anxius*, *Epelidoaegiria minuta minuta*, *Hedeina bruntoni*, *Janius bowningensis*, ambocoeliinae? gen. et sp. indet., *Morinorhynchus oepiki*, *Nanattegia yassensis*, *Skenidioides thrinax*, *Isorthis* (*Arcualla*) *salicipontis* [lower part, below Yarwood Siltstone Member], *Miniprokopia* sp. [below Yarwood Siltstone Member], *Dicoelosia* cf. *D. johnsoni*, *Salopina mediocostata*, *Salopina pusilla*, *Talentella yassensis* and *Tuvaerhynchus*? sp.

Ross (1961) described the bryozoan *Calopora hattonensis* from this unit.

From the upper part of the Black Bog Shale, above the Yarwood Siltstone Member, Rickards and Wright (1999) described a diverse dendroid and monograptid graptolite fauna consisting of *Dictyonema elegans*, *Dendrograptus* sp., *Pristiograptus dubius*, *P. shearsbyi*, *Linograptus posthumus posthumus*, *L. posthumus introversus*, *Bohemograptus bohemicus tenuis*, *B. praecornutus*, and *B. paracornutus*. Age of this fauna is, according to Rickards and Wright, equivalent to the late Ludlovian *praecornutus* biozone, and may potentially extend into the succeeding *cornutus* biozone in the top 2-3 m of the formation. Strusz (2010b) correlated these zones with the middle Ludfordian (middle to late Ludlovian).

Recently described from the Black Bog Shale is the new taxon *Porosothyone picketti*, the earliest-known holothurian body fossil (Jell 2010).

Probably also from this formation are bivalves described by Sherrard (1960), occurring on graptolite-bearing slabs; species recorded include *Actinopterella minuta*, *Pteronitella rugosa* and *Cardiola* (*Slava*) *fibrosa*.

<u>Yarwood Siltstone Member</u> (Shby on Fig. 2)

Some of the first fossils to be described from the Yass Basin came from the Yarwood Siltstone Member (initially termed the "Lower Trilobite Bed"), and included trilobites documented in a series of papers over two decades by Mitchell (1887, 1920) and Etheridge and Mitchell (1890, 1892, 1893, 1897, 1916, 1917). Revision of these faunas commenced fifty years later and continued for a further quarter-century (Chatterton 1971; Chatterton and Perry 1979; Chatterton and Campbell 1980; Strusz 1980; Thomas 1981; Adrain and Chatterton 1996). The fauna as currently recognised was listed by D. Holloway (in Pickett et al. 2000) and includes the following: *Australoscutellum longispinifex*, *Batocara bowningi*, *B. etheridgei*?, *B. mitchelli*, *B. robustum*, *B. rothwellae*, *Ceratocephala bowningensis*, *C. phalaenocephala*, *C. vogdesi*, *Crotalocephalus*? *sculptus*, *C*? *silverdalensis*, *Decoroproteus australis*, *Dudleyaspis bowningensis*, *Diacanthaspis* (*Acanthalomina*) *parvissima*, *Japonoscutellum jenkinsi*, *Prantlia yassensis*, *Scharyia ritchei*, *Scotoharpes trinucleoides*, *Sphaerexochus lorum*, *Staurocephalus mitchelli*, and *Tropidocoryphe rattei* [reassigned to the new genus *Cirriticeps* by Holloway (2013)]. To this list can be added *Cyphaspis horani*, according to Adrain and Chatterton (1996).

The brachiopod fauna is equally diverse. A few species were originally described by Mitchell (1921), but the entire fauna has since been fully documented by Strusz (2002, 2003, 2005b, 2007a, 2009, 2010a) who formally named several species that remained unpublished from the Ph.D thesis of Kemezys (1967). The fauna comprises *Barrandina wilkinsoni*, *Reticulatrypa pulchra*, *Atrypina* (*Atrypina*) cf. *A. latesinuata*, *Gracianella (G.*) *kausi yassensis*, *Gracianella* (*Sublepida*)? sp., *Atrypoidea* (*A.*) *australis*, *Leptaena compitalis*, *Desistrophia papilio*, *Endospirifer anxius*, *Mesopholidostrophia bendeninensis*, *Epelidoaegiria minuta minuta*, *Janius bowningensis*, *Hedeina bruntoni*, *Nanattegia yassensis*, *Spirinella caecistriata*, *Strophochonetes kemezysi*, *Morinorhynchus oepiki*, *Skenidioides thrinax*, *Dolerorthis exatripalude*, *Dicoelosia* cf. *D. johnsoni*, *Salopina mediocostata*, *Salopina pusilla*, *Talentella yassensis* and *Tuvaerhynchus*? sp.

McLean (1976) recorded and redescribed only one rugose coral from the Yarwood Siltstone Member, *Entelophyllum yassense patulum*, now referred to *Idiophyllum patulum* according to Munson et al. (2000). However, Strusz and Garratt (1999) listed a more diverse coral fauna including *Zenophila walli*, *Phaulactis shearsbyi*, *Tryplasma derrengullenense*?, *Mucophyllum* sp. and an unnamed sheet-like alveolitid. Probably from this level (according to Hill 1941:table B) came the specimen of the tabulate coral "*Pleurodictyum*" *problematicum* recorded by Foerste (1888). Plusquellec (2015:24) suggested that this specimen shows affinities with cf. *Petridictyum* n. gen. *sensu* Plusquellec (2007).

Crockford (1941) described several new species of bryozoa from this level, including *Penniretepora lobata*, *Pesnastylus humei* and *Pseudohornera*? *retiformis* (though there is some doubt about the stratigraphic horizon from which the latter was collected).

Etheridge (1890b) described the machaeridian *Turrilepas mitchelli*, and several scolecodonts (annelid worm jaws) referred to *Arabellites bowningensis*, *Eunicites mitchelli*, and *Oenonites hebes*, from this level – all are in need of revision.

Only one graptolite is presently known from the Yarwood Siltstone Member (Rickards and Wright 1999), the dendroid *Dictyonema* sp. cf. *D. sherrardae sherrardae*.

The fauna of the Yarwood Siltstone Member was selected by Strusz and Garratt (1999) as representative of their *Aegiria*–Alveolitid Community, part of the deeper-water brachiopod-dominated *Dicoelosia*–*Skenidioides* Community Group. They interpreted this high-diversity assemblage as inhabiting subtidal to mid-shelf marine environments assigned to BA4 in moderately agitated water.

<u>Rosebank Shale</u> (Shr on Fig. 2)

Excluding the diverse faunas of the Rainbow Hill Member (listed below), graptolites are the only fossils described from the Rosebank Shale (Jaeger 1967; Packham 1968; Rickards and Wright 1999, 2004). The fauna includes *Dictyonema* sp. cf. *D. sherrardae sherrardae*, *Dictyonema* spp., *Pristiograptus dubius*, *P. shearsbyi*, *P. kolednikensis*, *Linograptus posthumus posthumus*, *Monograptus formosus*, *M. parultimus*, *M. pridoliensis*, *Crinitograptus operculatus*, *Enigmagraptus yassensis*, *E. mitchelli* and '*Medusaegraptus*' sp. The presence of *M. parultimus*, nominative species of the *parultimus* Zone, indicates a basal Pridoli age for this fauna and hence the Rosebank Shale spans the late Ludlovian, just extending into the Pridolian.

<u>Rainbow Hill Member</u> (Shrr on Fig. 2)

Previously known as the "Middle Trilobite Bed", the trilobites of the Rainbow Hill Member have been described by Etheridge and Mitchell (1895, 1897), Mitchell (1919), Gill (1948), Chatterton (1971), Sherwin (1971), Strusz (1980), Sun (1990), and Ramsköld (1991). Currently recognized species were listed by Holloway (in Pickett et al. 2000:164) and include *Ananaspis latigenalis* [referred to *Paciphacops latigenalis* by Edgecombe and Ramsköld 1994], *Batocara robustum*, *Dalmanites meridianus*, *Decoroproteus yassensis*, *Dicranurus longispinus*?, *Kettneraspis rattei*, *Latiproteus bowningensis*, *Malimanaspis rhaptomyosa*, *Miraspis impedita*, *M. jackii*, and *Radnoria elongata*. Reassignment of *Odontochile meridianus* to *Dalmanites* implies that the trilobite-dominated *Odontochile* Community established by Strusz and Garratt (1999) to characterise the fauna of the Rainbow Hill Member should be renamed the *Dalmanites* Community. This fauna inhabited quiet deeper water environments corresponding to BA4.

Strusz (2002, 2003, 2007a, 2007b) described the following species of brachiopods from the Rainbow Hill Member: *Leptaena compitalis*, *Mesoleptostrophia* (*Mesoleptostrophia*) *quadrata*, *Plectodonta* (*Plectodonta*) *psygmata*, *Strophochonetes kemezysi*, *Salopina mediocostata*, *Salopina rainbowella*, *Talentella yassensis*, gen. et sp. indet. cf. *Becscia* sp., *Spirigerina mitchelli* and *Nucleospira paula*. A possible occurrence of *Clorinda minor* in this unit was noted by Strusz (2005b).

The bivalve *Goniophora* sp. was recorded by Sherrard (1960) as very rarely occurring in the Middle Trilobite Bed (=Rainbow Hill Member) at Bowning.

McLean (1976) redescribed the rugose coral *Palaeocyathus australis* from this unit, its only occurrence in the Yass succession.

The cystoid (echinoderm) *Austrocystites branagani*, first described by Brown (1964) from the Rainbow Hill Member, was redescribed and assigned to the genus *Eucystis* by Jell (2010). Another cystoid fragment from a similar stratigraphic level, identified as *Palaechinus* by Mitchell (1897), was reassigned to the new species *Trematocystis wrighti* by Jell (2010).

<u>Cowridge Siltstone</u> (Shc on Fig. 2)

Graptolites from the Cowridge Siltstone were first described by Sherrard and Keble (1937), and Brown and Sherrard (1952), although due to misidentifications they inferred a considerably older age than is now known to be the case. Jaeger (1967) discussed the earlier identifications and figured a specimen of *Monograptus bouceki* from this level. The fauna was revised and expanded by Rickards and Wright (1999) to include *Dictyonema* spp., *Pristiograptus shearsbyi*, *Monograptus parultimus*, *M. bouceki*, *M. transgrediens*, and *Monograptus* sp. *Monograptus parultimus* occurs in the lower part of the formation and *M. bouceki* first appears approximately 30 m higher, indicating that the Cowridge Siltstone spans both the *parultimus* and *bouceki* zones of the early to middle Pridoli.

Brachiopods described by Strusz (2002, 2003, 2007a, 2007b, 2010a) from the Cowridge Siltstone include *Strophochonetes kemezysi* and *Nanattegia yassensis* (both in basal beds of the formation), *Endospirifer anxius*, *Plectodonta* (*Plectodonta*) *bipartita*, *Meifodia*? cf. *M. lenticulata*, *Salopina pusilla*, *Talentella yassensis*, *Nucleospira paula* and *Navispira*? *bicarinata*.

A gastropod collected at Bowning, identified by Tassell (1980) as *Australonema*? sp. B, probably came from this formation.

Elmside Formation (She on Fig. 2)

The lower mudstone-dominated part of the Elmside Formation is of *transgrediens* Zone age (i.e. latest Pridoli Stage, or terminal Silurian), indicated by a graptolite fauna first described by Jenkins (1982a), and revised and expanded by Rickards and Wright (1999) who identified *Dictyonema elegans*, *Linograptus posthumus posthumus*, *Pristiograptus shearsbyi*, *Monograptus transgrediens*, *M. perneri elmsidensis*, *M. hornyi*, and *M. formosus jenkinsi*.

Brachiopods present in this latest Pridoli section (described by Brown 1949; Strusz 2000, 2003) include *Plectodonta* (*Plectodonta*) *bipartita* and *Strophochonetes kemezysi*.

Sherrard (1960) described numerous bivalves from this level, including *Nuculites pseudodeltoides*, *N. scissa*, *Ctenodonta* (*Tancrediopsis*) *victoriae*, *C.* (*T.*) *elegantula*, *C.* (*T.*) *minuta*, *Grammysia* (*Grammysioidea*) *declivis*, *G. ampla*, *Actinopterella lamellosa*, *A. minuta*, *Nuculopsis triangula*, *Rhombopteria laminosa*, *Lunulicardium* sp., *Modiolopsis elongata*, *Paracardium* cf. *P. filosum*, *Cypricardinia contexta* and *Paracyclas orbiculata*.

Echinoderms are represented by a unique starfish described by Etheridge (1899) as *Sturtzaster mitchelli* – unfortunately this specimen was unable to be located in the Australian Museum collections, and is presumed lost. The new genus and species *Porosothyone picketti*, described by Jell (2010) from this unit, is the earliest-known holothurian body fossil (also present in the Black Bog Shale).

The nautiloid *Graftonoceras bowningensis*, originally described by Etheridge (1904a) as a species of *Cyclolituites* but reassigned by Teichert and Glenister (1952), possibly comes from the lower beds of the Elmside Formation (fide Strusz 1996).

Conodonts identified as early Lochkovian (*woschmidti* Zone) in age were described by Link and Druce (1972) from limestone lenses in the Elmside Formation above the graptolitic mudstones in the lower part of the unit. Klapper and Johnson (1980) re-identified these conodonts as *Icriodus hesperius* (now *Caudicriodus hesperius*), an indicator of the basal conodont zone of the Early Devonian Lochkovian Stage.

Wright (1981) described the brachiopod *Notanoplia mitchelli* from the upper part of the Elmside Formation; an illustrated specimen doubtfully attributed to this species by Wright was reassigned by Talent et al. (2001:159) to *Notoparmella plentiensis* Garratt.

The trilobite *Leonaspis jenkinsi* was mentioned by Edgecombe (in Talent et al. 2000:205) as occurring in the Elmside Formation. Sherwin (1971) redescribed the trilobites "*Phacops*" *serratus* and "*Phacops*" *crosslei* [=*Ananaspis crosslei*] from the "Upper Trilobite Bed" in the upper part of the Elmside Formation. Other trilobites from this level include longer-ranging taxa that first appear in the Yarwood Siltstone Member or Rainbow Hill Member, according to Strusz (1989, 1995), such as *Leonaspis rattei*, *Latiproetus bowningensis* and *Maurotarion bowningensis*.

Fletcher (1938, 1946) described the conularids *Conularia chapmani*, *C. mitchelli* and *C. bowningensis* from the "Upper Trilobite Bed". These were revised by Sherwin (1969), who recognised *C. mitchelli* as a crushed nautiloid specimen; the other two species are valid.

From the 'lower Gedinnian' (i.e. earliest Devonian) part of the Elmside Formation, Birkhead (1978) described the stromatoporoids *Stachyodes* cf. *S insignis* and *Stromatopora foveolata*, and Pickett and Jell (1974) described a new species of tabulate coral, *Hattonia fascitabulata*.

A primitive plant identified as *Dawsonites racemosa*, illustrated by White (1986), was found near Bowning. Trilobite pygidia of Early Devonian age associated with the specimen suggests that it comes from the Elmside Formation.

REGIONAL SILURIAN TO EARLIEST DEVONIAN STRATIGRAPHY OUTSIDE THE YASS BASIN

Campbells Group

Kildrummie Formation (Sci on Fig. 2)

In their revision of a late Silurian conodont fauna originally described (in form species nomenclature) by De Deckker (1976) from the type section of the Kildrummie Formation, 11 km south of Rockley, Simpson and Talent (1995) and Simpson (1995) interpreted elements identified as "*Spathognathodus crispus*" and "*S. snajdri*" by De Deckker to be Pa elements of *Kockelella ranuliformis*, hence placing an age limit no younger than the basal *siluricus* Zone of the Yass Basin succession. Serpagli and Corradini (1999), who studied contemporaneous faunas from Sardinia, restricted the upper limit of *K. ranuliformis* to the mid-Wenlockian, near top of the Sheinwoodian (uppermost *Ozarkodina sagitta rhenana* Zone), although the species could conceivably range into the succeeding lower Homerian *sagitta* Zone. Simpson and Talent (1995) also recognised *Coryssognathus dubius* (comprising elements referred to the form species "*Dialdelognathus primus*", "*Distomodus curvatus*" and *Acodus* cf. *curvatus* by De Deckker

1976), implying a Ludlovian age for the upper part of the Kildrummie Formation.

Mitchell (1923) described *Stropheodonta tarloensis* from outcrops now mapped as Kildrummie Formation in the Tarlo River southwest of Taralga; this brachiopod was tentatively reassigned to *Aegiria* (*Epelidoaegiria*) by Strusz (1982) but was subsequently considered by Strusz (2003:17) to be a *nomen dubium*, too poorly preserved to be confidently identified.

Cuddyong Formation (Scc on Fig. 2)

Fossils are sparse in the Cuddyong Formation, and consist of poorly preserved conodonts and occasional corals in limestones that are non-diagnostic of age. A graptolite found in the unit about 4.5 km west of Tuena, identified by L. Sherwin as *Bohemograptus* (possibly *B. bohemicus* subsp.), is indicative of a Ludlovian (late Silurian) age. Sherwin (cited in Percival 2012b) noted that while preservation is poor, the characteristic sickle shape of the rhabdosome is clear, as are a couple of thecae.

Mount Fairy Group

Shivering Conglomerate (Sfi on Fig. 2)

The only fossiliferous site known from this unit is located on the Oberon 1:100,000 mapsheet, immediately north of the boundary with the Taralga 1:100,000 mapsheet (Percival and Sherwin 2005). The lithology at this outcrop is heavily silicified, with poorly preserved macrofauna including a small rugose coral with long septa, resembling *Palaeophyllum*. Cross-sections of brachiopods observed in outcrop indicate the presence of pentamerides, implying most likely a Wenlockian or Ludlovian age.

Cobra Formation (Sfr on Fig. 2)

Valentine et al. (2006) documented a diverse fauna of linguliformean brachiopods and conodonts from the type section of the Cobra Formation in Murruin Creek near Taralga. Species described include the brachiopods *Kosagittella*? sp., *Rowellella*? sp., *Paterula* sp., *Orbiculoidea* sp., *Schizotreta* sp., *Artiotreta longisepta*, *Acrotretella dizeugosa*, *Opsiconidion ephemerus* and *O.* sp., together with several indeterminate taxa. The conodont fauna includes *Belodella anomalis*, *Dapsilodus obliquicostatus*, *Decoriconus fragilis*, *Panderodus recurvatus*, *P. serratus*, *P. unicostatus*, *Coryssognathus dubius*, *Oulodus* cf. *O. elegans*, *Wurmiella excavata excavata* and *Kockelella maenniki*. The last-named species is restricted to the early to middle *P. siluricus* Zone of the middle Ludlovian in Europe and North America (Serpagli and Corradini 1999), implying a similar age for the sample near the top of the Cobra Formation in which it occurs. The formation may be as old as mid-Wenlockian at its base, according to Valentine et al. (2006), although a maximum late Wenlockian age – interpreted from coral faunas corresponding to the Hattons Corner Assemblage of Strusz and Munson (1997) and Munson et al. (2000) – is more plausible.

Another limestone sample from the Cobra Formation (Percival and Sherwin 2005) yielded numerous conodont elements, most of which are long-ranging species including *Panderodus unicostatus* and *Wurmiella excavata excavata*. The only biostratigraphically significant species, *Kockelella variabilis*, was represented by two fragmentary Sc elements and one broken but highly distinctive Pb element. This restricts the age of the sample to no younger than the basal *Polygnathoides siluricus* Biozone (middle Ludlovian), with a maximum age likely approximating the base of the Ludlow (late *K. crassa* Biozone) (Serpagli and Corradini 1999), although the species has been reported from Wenlock strata in China (Wang 2013).

Macrofossils in the Cobra Formation are present at two localities on the Taralga 1:100,000 mapsheet, where they occur as pavements of shelly fauna on bedding planes. Brachiopods are dominant, with *Mesopholidostrophia* cf. *M. bendeninensis* the most abundant, associated with *Atrypoidea* sp. and *Howellella* cf. *H. elegans*. The trilobite *Batocara* cf. *B. mitchelli* is present sporadically. Apart from hydrodynamic sorting, the bedding plane assemblages look to be largely undisturbed by waves, with all shells unbroken and some still articulated. Strusz (2003) noted that *M. bendeninensis* has a mid Ludlovian age, with the possibility that it might range to the end of the Ludlovian.

Evidence for the age of the Cobra Formation from both conodonts and macrofauna therefore is mostly consistent with a Ludlovian age, probably no younger than the top of the *siluricus* Zone, but potentially extending into the mid to late Wenlockian at its base.

De Drack Formation, Kingsdale Limestone Member (Sfdk on Fig. 2)

The Kingsdale Limestone Member contains a macrofauna characteristic of a quite shallow water depositional environment, evidenced by the presence of megalodont bivalves in the Kingsdale Limestone Quarry (near Goulburn). Although stromatoporoids are fairly common, other macrofauna is neither abundant nor diverse, with brachiopods (apart from occasional disarticulated pentamerides) poorly

represented. Conodonts are relatively uncommon to rare in the unit, with only one biostratigraphically useful species recovered. *Kockelella ranuliformis* (found in GSNSW conodont sample C1938, and questionably in C2058) is characteristic of a conodont biozone named for the species, but it also occurs in the underlying *Pterospathodus amorphognathoides* Zone that spans the Llandovery–Wenlock boundary and ranges upwards into the early Wenlockian *K. amsdeni* to *K. variabilis* zones (Bischoff 1987).

The age of the Kingsdale Limestone Member therefore is most likely confined to the mid-Wenlockian, ranging from the upper *K. amsdeni* Zone into the overlying *K. variabilis* Zone. This is broadly in accord with limited data available from associated macrofossils. For example, a rugose coral from the Kingsdale Limestone Member, identified as *Cyathactis* cf. *C. variabilis*, is similar to *C. variabilis* from the Rosyth Limestone of the Boree Creek area, west of Orange (McLean 1975). The Rosyth Limestone is assigned to the *Pterospathodus amorphognathoides* conodont Zone, which spans the Llandovery–Wenlock boundary. However, the range of the coral *Cyathactis* extends into the Ludlovian.

<u>Sooley Volcanic Member</u> (Sfds on Fig. 2)

GSNSW conodont sample C1962, from an allochthonous limestone block surrounded by Sooley Volcanic Member rocks in the upper De Drack Formation (above the Kingsdale Limestone Member), yielded a single specimen most likely referrable to the distinctive conodont *Belodella anomalis*, which is known to range from the mid-Ludlovian *siluricus* Zone (basal Ludfordian) up to the top of the Pridolian.

<u>Joppa Siltstone Member</u> (Sfdj on Fig. 2)

The graptolite *Bohemograptus bohemicus* subsp. was found in an outcrop of the Joppa Siltstone Member behind the pumphouse at the Goulburn Waterworks Museum. This indicates a late Silurian (early to mid Ludlovian) age (Percival and Sherwin 2004).

<u>Undifferentiated De Drack Formation</u> (Sfd on Fig. 2)

A graptolite fauna including both the *bohemicus* and *tenuis* subspecies of *Bohemograptus bohemicus*, found in black shale of the undifferentiated De Drack Formation near Wowagin Creek, west of Taralga (Percival and Sherwin 2005), indicates a mid to late Ludlovian age (*scanicus* to *leintwardinensis* zones).

Several fossiliferous localities on the Braidwood 1:100,000 mapsheet are assigned to undifferentiated De Drack Formation (Percival and Sherwin 2008). On "Mulloon Creek", a large coarsely ribbed pentameride brachiopod has been identified as *Kirkidium (Pinguaella)* by D.L. Strusz. Another site yielded the graptolite *Bohemograptus bohemicus* subsp., found elsewhere in the Joppa Siltstone Member (see above) and in the Kerrawary Siltstone overlying the De Drack Formation. Conodonts recovered from a limestone within the De Drack Formation in this area include *Panderodus recurvatus*, *Wurmiella excavata*, *Pseudooneotodus beckmanni*, and a coniform element of *Coryssognathus dubius*.

<u>Kerrawary Siltstone</u> (Sfy on Fig. 2)

Although most specimens of graptolites from this formation are poorly preserved or are distorted by cleavage, sufficient of the diverse fauna has been identified to constrain the age of the unit quite precisely to the *nilssoni* and overlying *scanicus* zones of the early Ludlovian (Percival and Sherwin 2004; Percival 2012b). Species recognised in the region east of Goulburn (identifications by L. Sherwin; not all are co-occurring) include *Bohemograptus bohemicus* subsp., *Neodiversograptus nilssoni*, *Monograptus dubius*, *M. dalejensis*, *M.* sp., *Cucullograptus progenitor cudalensis*, *Linograptus* cf. *L. orangensis* and *Saetograptus chimaera*. Associated macrofossils include a small strophomenide brachiopod, possibly *Aegiria* sp. or *Epelidoaegiria* sp. Of this fauna, only one species (*B. bohemicus*) has previously been described and illustrated (as *Monograptus bohemicus*) from the Taralga region, by Naylor (1936). Two of these taxa – *Cucullograptus progenitor cudalensis* and *Linograptus* cf. *L. orangensis* – were previously recognized in the Spring Creek and Quarry Creek region southwest of Orange (Rickards et al. 1995).

Limestone exposed in an abandoned quarry at Jerrara Creek, NW of Bungonia (GR 765575 6144050, Goulburn 1:100,000 mapsheet), was previously mapped as an allochthonous block occurring within the early Silurian Jerrara Formation, on the basis of a conodont fauna determined (by Percival 2012b) to be of late Llandovery to earliest Wenlock age. The limestone at Jerrara Creek yielded more than 200 conodont elements, many of which are deformed, with a CAI of 4.5 to 5. Reappraisal of this conodont fauna (Peep Männik, pers. comm. 2016) suggests that the age is considerably younger – most likely mid Ludlow (lower-middle *Polygnathoides siluricus* Biozone), based on the identification of *Kockelella maenniki* Serpagli and Corradini, 1998 (Fig. 4c-h). Associated conodonts (Figs 4i-s, 5, 6b-s, 7) include *Kockelella* sp. A, *Kockelella* sp. B, *Kockelella* sp. C, *Ozarkodina* sp., *Panderodus* sp. nov. and *Wurmiella excavata*. Also present are beyrichian ostracodes and an acrotretid brachiopod. *Kockelella maenniki*

has previously been recorded in the type section of the Cobra Formation in Murruin Creek near Taralga (Valentine et al. 2006). Though the Cobra Formation does not occur on the Goulburn 1:100,000 mapsheet, a slightly younger unit in the Mount Fairy Group, the Covan Creek Formation, is mapped between Goulburn and Bungonia wrapping around a very narrow tract of Jerrara Formation that includes large isolated limestone outcrops. All stratigraphic boundaries between these formations are depicted as inferred faults on the published map (they could also be interpreted as disconformable boundaries, though given the discontinuity of outcrop in the area it is difficult to be certain of their true nature). To explain the presence of a middle Ludlow limestone apparently occuring within the late Llandovery Jerrara Formation, one solution would be to reassign the siltstone beds in which the limestone blocks are emplaced to Kerrawary Siltstone, which has been mapped in this region, is of the right age, and underlies the unfossiliferous Covan Creek Formation. Alternatively, the boundaries between units might be better placed on the western side of the limestone blocks, thereby separating the early Silurian succession to the west from the late Silurian Mount Fairy Group to the east.

<u>Boxers Creek Formation</u> (Sfb on Fig. 2)

The brachiopod *Notanoplia* sp. and a trilobite referred to *Phacops* sp. have been identified from strata now attributed to the Boxers Creek Formation, near the top of that formation (Sherwin 1968, 1974). These fossils were obtained in the vicinity of the Bungonia Road–Kooringaroo Road junction, and in a nearby creek. They most likely indicate a Pridolian (latest Silurian) to Lochkovian (earliest Devonian) age.

<u>Rhyanna Formation</u> (Sfh on Fig. 2)

Various ages were obtained from allochthonous limestone blocks emplaced as an olistostrome near the base of the Rhyanna Formation (Percival and Sherwin 2005). The oldest, of late Wenlockian (latest Sheinwoodian to lower Homerian) age, was derived from a conodont fauna including *Panderodus unicostatus*, *P. panderi*, *Coelocerodontus* sp., *Wurmiella excavata* s.l. and *Ozarkodina sagitta sagitta*, the latter (represented by a Pa and possible Sa elements) providing the definitive age constraint. Sections of another limestone revealed crinoid ossicles, heliolitid corals, *Thamnopora* (a thick-walled favositid coral), a tryplasmatid rugose coral, and a laminar stromatoporoid exhibiting well-developed astrorhizal canals (but not sufficiently well preserved for identification). The *Thamnopora* is similar to a species common in the Nandillyan and Molong Limestones of the northern Molong High (J.W. Pickett, pers. comm.), suggesting a generalised Wenlockian to Ludlovian age. The residue of this sample (GSNSW conodont sample C2200) yielded conodonts with younger and inconsistent ages, implying that a variety of allochthonous limestone clasts were collected and processed together. Species identified included the long-ranging *Panderodus unicostatus*, *Belodella anomalis* which ranges from the *siluricus* Zone of the middle Ludlovian to the top of the Pridolian, and *Zieglerodina paucidentata*. This latter species is restricted to the basal Lochkovian *woschmidti/hesperius* to *eurekaensis* zones, and does not overlap with the range of *Belodella anomalis* (although these species do occur in adjacent zones at the Silurian/Devonian boundary). Another sample yielded *Zieglerodina remscheidensis* which ranges from the basal Pridolian (*eosteinhornensis* Zone) to the middle Lochkovian *delta* Zone. The most productive sample (GSNSW C2193) included *Caudicriodus hesperius* (zonal indicator for the early Lochkovian *woschmidti-hesperius* Zone), *Wurmiella excavata*, *Oulodus* sp., *Panderodus unicostatus*, *P. recurvatus*, and *Belodella resima*. That assemblage indicates an earliest Devonian depositional age for the lower Rhyanna Formation.

<u>Gundary Volcanics</u> (Sfg on Fig. 2)

An allochthonous limestone (Sfgl; GSNSW conodont sample C1939) in the Gundary Volcanics yielded more than 100 conodont elements including *Panderodus unicostatus*, *Belodella anomalis*, *Wurmiella excavata excavata*, *Kockelella* sp. (Pa and Sb elements), together with the lingulate brachiopod *Opsiconidion* sp. (Percival and Sherwin 2004). Although this occurrence provides a maximum late Silurian age, ranging from the mid-Ludlovian *siluricus* Zone i.e. basal Ludfordian, to the top of the Pridolian, regional correlations suggest that the depositional age of the Gundary Volcanics is Early Devonian (Thomas and Pogson 2012).

<u>Longreach Volcanics, Brayton Limestone Member</u> (Sflb on Fig. 2)

Sampling of this unit (GSNSW conodont sample C1893), exposed in the Longreach limestone quarry on the Goulburn 1:100,000 mapsheet, yielded four conodont elements, including *Wurmiella excavata excavata* and *Amydrotaxis* sp., the latter indicating a Lochkovian to Pragian age (Percival and Sherwin 2004).

Bungonia Group

Cardinal View Formation, Lookdown Limestone Member (Sbcl on Fig. 2)

Hundreds of conodont elements have been recovered from insoluble residues of the Lookdown Limestone Member (Percival and Sherwin 2004), but these are predominantly panderodids. Most useful biostratigraphically are platform (Pa) elements of *Ancoradella ploeckensis*, which is the index species for the *ploeckensis* Zone (early Ludlovian) and also ranges into the succeeding *siluricus* Zone of mid Ludlovian age. Also rarely present in residues of the member (GSNSW conodont sample C2030) are Pb and M? elements of a large *Ozarkodina*; these resemble *Ozarkodina* sp. nov. (illustrated in Percival 1998: fig. 4.3-4.4) from allochthonous limestone blocks in the Barnby Hills Shale. The suggested age for those *Ozarkodina* is early to mid Ludlovian, which accords with the age deduced for the Lookdown Limestone Member. Elements from GSNSW conodont sample C2012 that were attributed (by Percival and Sherwin 2004) to the Pa element of *Kockelella ranuliformis* are closely comparable (if not identical) with specimens identified by Link and Druce (1972:pl. 9, figs 22-28) as the form-species '*Spathognathodus* sp. cf. *S. ranuliformis*' from the lower part of the Yass Basin succession.

Cook (1994) described a gastropod, *Michelia bauerae*, and subsequently (Cook 1995) described a new genus and species of a megalodont bivalve *Schismadon bungoniensis* from the Lookdown Limestone Member, which has also yielded the rugose corals *Bungoniella clarkei* and *Hedstroemophyllum* sp. (Wright and Bauer 1995).

Shales overlying the Lookdown Limestone Member contain a graptolite fauna, reported by Carr et al. (1980) to include *Bohemograptus bohemicus tenuis*, indicating a mid-Ludlovian age.

Frome Hill Formation (Sbf on Fig. 2)

Copeland (1981) described a new genus of ostracode, *Bungonibeyrichia*, from "near the top of the upper shale unit, Bungonia Limestone" which suggests a level equivalent to the Efflux Siltstone Member of Bauer (1994), within the Frome Hill Formation above the Folley Point Limestone Member (Sbff on Fig. 2). Camilleri et al. (2017) recently reassessed the species identification, describing *B. copelandi* and designating it as the type species of this taxon. The Frome Hill Formation also contains brachiopods, identified as *Eospirifer eastoni* and *Schizophoria* sp. by Jones et al. (1981), a trilobite referred by them to *Scabriscutellum* cf. *S. scabrum*, together with a conodont identified by Jones et al. as "*Spathognathodus* cf. *S. remscheidensis*" which supported a Lochkovian age for the upper Bungonia Limestone. However, Mawson (1986) reassigned that conodont to *Ozarkodina steinhornensis eosteinhornensis*, indicative of a Pridolian age, and rejected the brachiopod identifications of Jones et al. (1981) due to inadequacy of the available material. Mawson also suggested that the trilobite belonged to the long-ranging subgenus *Scutellum* (*Scutellum*), but this identification has subsequently been rejected (Camilleri et al. 2017). Wright and Bauer (1995) mention the subsequent recovery of the characteristically Devonian brachiopod *Cyrtina* from the Sawtooth Ridge Limestone Member (not shown on Fig. 2) which forms the uppermost unit of the Frome Hill Formation.

EARLY TO MIDDLE DEVONIAN STRATIGRAPHY OF THE BURRINJUCK AREA

Black Range Group

Sharpeningstone Conglomerate (Dbh on Fig. 2)

Reworked clasts in the Sharpeningstone Conglomerate, derived from underlying Silurian strata (and hence providing evidence of the Bowning Orogeny) contain fragments of corals *Halysites* sp. (Wright and Byrnes 1980), *Aphyllum lonsdalei* and *Phaulactis shearsbyi* (identified by Link and Druce 1972), and the rhynchonellide brachiopod *Tuvaerhynchus*? sp. described by Strusz (2009). The latter is otherwise only known from the Black Bog Shale and its Yarwood Siltstone Member in the Yass Basin. Link and Druce also identified 11 form species of conodonts from clasts in the conglomerate, spanning four of their assemblage zones and thereby implying that the erosion associated with the orogenic episode had sampled virtually the entire Yass Basin succession.

Kirawin Formation (Dbk on Fig. 2)

Maldybulakia angusi, a terrestrial myriapod arthropod, was described by Edgecombe (1998) from the Sugarloaf Creek Formation east of the Mountain Creek Road, about 5 km south of its junction with the Taemas–Wee Jasper road. However, some doubt exists regarding the precise stratigraphic level of this site (see discussion in Young 2011:87) as it corresponds to locality 10 of Campbell (1976), who attributed the strata to the underlying Kirawin Formation to which it probably belongs.

Sugarloaf Creek Formation (Dbs on Fig. 2)

The only fossil definitely known from this unit is

an undescribed fish plate assigned to the placoderm *Groenlandaspis*? (A. Richie, pers. comm. 1993) collected from material excavated during roadworks near the entrance to “Fifeshire” property on the lakeside road from Good Hope.

Murrumbidgee Group

Overview of palaeontological research

The Taemas–Wee Jasper area at the southern boundary of the Yass 1:100,000 mapsheet includes another series of significant palaeontological localities, such as the heritage-listed site known as ‘Shearsby’s Wallpaper’, world-famous fossil fish sites (Young 2011), and a rich and diverse invertebrate fauna that has been the subject of much research over the past century and a half. The Early Devonian biostratigraphy of this area was established by Philip and Jackson (1967), Philip and Pedder (1967) and Pedder et al. (1970), who documented a series of conodont zones and coral faunas in the Goodradigbee River valley exposures immediately north of Wee Jasper. Garratt and Wright (1988) integrated these zonations with their own Assemblage Zones based on brachiopods to provide an expanded macrofossil-based biostratigraphy with wide applicability to Lower Devonian rocks throughout NSW and Victoria.

Descriptions of conodont form species from the Wee Jasper area published in Pedder et al. (1970) have been superseded by modern conodont studies of Mawson et al. (1989) and Mawson and Talent (2000), culminating in a precise zonation for the Murrumbidgee Group (Basden 2003). The oldest conodont fauna (from the Cavan Bluff Limestone) is now confirmed as late Pragian (*pireneae* Zone) in age (Mawson et al. 1992), whereas that from the uppermost Taemas Limestone indicates a late Emsian age (*serotinus* Zone – Mawson 1987).

Fish faunas, both macrofossil and micro-vertebrate, have assumed increasing importance in Early Devonian biostratigraphy and regional correlation in recent years as the diversity of these fossils is explored, and their distribution is tied into the conodont zonation (Basden et al. 2000). Young (2011) summarised the history of research into fossil fish of the Murrumbidgee Group, with notable early contributions by Etheridge (1906) who described a lungfish skull (subsequently named *Dipnorhynchus*) found near old Taemas Bridge, Woodward (1941) who described the skull of the placoderm *Notopetalichthys hillsi*, and White (1952, 1978) who pioneered the technique of acid-etching limestone to obtain three-dimensional specimens of fish skulls from the Burrinjuck region. A major research program at ANU, Canberra, led by K.S.W Campbell documented the lungfish fauna (Campbell and Barwick, 1982-2007; Campbell et al. 2009), while the diverse placoderm fauna was described by G. Young and co-workers in publications spanning 1978-2009. A complete listing of papers describing Devonian fish from the Burrinjuck region to 2010 is given by Young (2011).

Rugose corals, initially studied by Etheridge (1892a, 1902, 1920) and Hill (1941) and subsequently comprehensively revised by Pedder (1964, 1965, 1967; in Pedder et al. 1970), are prominent in the Taemas and Wee Jasper areas. Currently-accepted rugose coral genera from the Cavan Bluff and Taemas limestones are listed by Zhen et al. (2000).

Other significant components of the invertebrate fauna of the Murrumbidgee Group have been described in several major monographic works (based on higher degree projects undertaken at ANU, Canberra under supervision of K.S.W. Campbell). Trilobites and associated brachiopods of the Taemas Limestone were described by Chatterton in 1971 and 1973 respectively. Ostracodes from the Taemas Limestone were documented by Reynolds (1978), and the gastropods have been described by Tassell (1982). Johnston (1993) provided the definitive systematic account of bivalves from the Cavan Bluff and Taemas limestones.

Cavan Bluff Limestone (Dmc on Fig. 2)

The Cavan Bluff Limestone [= Cavan Formation of previous authors] is well-dated on the basis of conodonts that were initially studied by Philip and Jackson (1967) and more extensively documented by these authors in Pedder et al. (1970). Subsequent revisions by Mawson et al. (1992) identified the Pragian-Emsian boundary, defined by the first appearance of the conodont *Polygnathus dehiscens dehiscens* (previously identified as *P. linguiformis dehiscens* by those authors), as occurring within the Cavan Bluff Limestone approximately 72 m above the base of the section measured at Wee Jasper (just south of the boundary of the Yass 1:100,000 mapsheet). Species recovered by Mawson et al. included (in addition to non-platform elements) *Oulodus murrindalensis*, *Ozarkodina buchanensis*, *O. linearis*, *O. prolata*, *O. pseudomiae*, *O. selfi*, *Pandorinellina exigua philipi*, *Polygnathus dehiscens abyssus* and *P. pireneae*. The latter is the index species for the latest Pragian *pireneae* Zone, which is represented in the lower Cavan Bluff Limestone.

Rugose corals were described from the Cavan Bluff Limestone initially by Etheridge (1902) and Hill (1941), with systematic revisions given by Pedder (1964, in Pedder et al. 1970). Genus reassignments by Zhen et al. (2000) and Pickett (2010) are reflected

in the following faunal list: *Pseudomicroplasma australasica*, *Embolophyllum aequiseptatum aequiseptatum*, *Tipheophyllum bartrumi*, *Sterictophyllum trochoides*, *Zelolasma gemmiforme*, *Z. abrogatum* and *Z. curtum*. Tabulate corals are abundant, notably *Favosites murrumbidgeensis*.

Bivalves were described by Johnston (1993) from calcareous sandstone and siltstone in the Cavan Bluff Limestone south of Mountain Creek (immediately south of the Yass 1:100,000 mapsheet boundary). He recorded the following fauna: *Nuculopsis* sp., *Polidevcia* cf. *P. insolita*, *Mytilarca bloomfieldensis*?, *Glyptodesma buchanensis*, *Goniophora pravinasuta*?, *Guerangeria* sp., *Sanguinolites*? *concentrirugosa*, and *Schizodus oweni*.

The brachiopod *Spinella yassensis* first appears in the Cavan Bluff Limestone, although according to Strusz et al. (1970) it may be a different subspecies to that found in the lower Taemas Limestone. Chatterton (1973) also recognised *Athyris waratahensis* in the Cavan Bluff Limestone (confirmed by Talent et al. 2001).

Long (1986) and Lindley (2000) described acanthodian fish remains including jawbones with teeth, fin spines and scales, from exposures around Lake Burrinjuck between Taemas and Good Hope. Species described include *Taemasacanthus erroli*, *T. porca*, *Cavanacanthus warrooensis* and *Cambaracanthus goodhopensis*. According to Lindley (2002b:fig. 5) all specimens came from flaggy limestone associated with shale and quartzite in the basal part of the Cavan Bluff Limestone; *T. erroli* is also shown as ranging up into more massive algal limestones in the middle part of the formation, and also occurs in the lower units of the Taemas Limestone. Burrow (2002), however, argued that the incomplete nature of the specimens described by Lindley (2000) potentially allowed them all to be synonyms of *T. erroli*. An indeterminate ischnacanthid scale figured by Lindley is referred by Burrow to *Gomphonchus*? *bogongensis*. A new genus and species of arthrodire, *Bimbianga burrinjuckensis*, was described by Young (2005) from the Cavan Bluff Limestone just north of the Goodradigbee Valley, where it is associated with the arthrodire *Cavanosteus australis* described by Young (2004b). Campbell et al. (2009) noted fragmentary dipnoan material possibly referable to *Speonesydrion iani* from the lower part of the Cavan Bluff Limestone. Thelodont scales assigned to *Turinia* cf. *T. australiensis* were described and illustrated by Basden (1999) from the Cavan Bluff Limestone, and Basden (in Basden et al. 2000) and Basden (2003) illustrated a variety of fish scales and bone from this formation in a road section on the north side of the Taemas Bridge; these include material from thelodont, placoderm (including *Goodradigbeeon* sp.), acanthodian (including *Cheiracanthoides* sp.), chondrichthyan and dipnoan fish. The same exposure yielded an echinoid, *Cavanechinus warreni*, described by Brown (1967).

<u>Majurgong Formation</u> (Dmj on Fig. 2)

Fletcher (1964) described *Lingula murrumbidgeensis* from strata now referred to the Majurgong Formation at a locality given as "beyond woolshed on Bloomfield Station" in the Taemas district. Lingulide brachiopods are common elsewhere in maroon siltstones of this formation, such as in the Good Hope area. No internal details of this species have been described, and its generic attribution is in need of reassessment.

Microvertebrate remains illustrated from limestones in the Majurgong Formation in the vicinity of Taemas Bridge (Basden 2003) include *Ohiolepis* sp., *Onychodus* sp., and scales of *Ligulalepis toombsi*.

<u>Taemas Limestone</u> (Dmt on Fig. 2)

Rugose corals were described from the undifferentiated Taemas Limestone in the Wee Jasper area by Pedder (in Pedder et al. 1970), who established five informal 'tetracoral teilzones' (essentially range or interval zones) within this section. In stratigraphical order from oldest to youngest these are: *Chalcidophyllum recessum* zone, *Embolophyllum aggregatum aggregatum* zone, *Vepresiphyllum falciforme* zone, *Hexagonaria smithi smithi* zone, *Chalcidophyllum vesper* zone. These zones are difficult to apply precisely to the sections exposed around the eastern perimeter of the Burrinjuck Reservoir (Taemas–Good Hope), as this and the Wee Jasper areas only share similar coral species in the three lower zones. Due to the demonstrably diachronous nature of the contact with the underlying Majurgong Formation, the base of the Taemas Limestone is younger in the Wee Jasper area (where it probably lacks equivalents of the Spirifer yassensis Limestone Member, according to Pedder et al. 1970) than at Taemas. The Taemas Limestone at Wee Jasper may also extend slightly higher than in the Taemas succession. Remapping of the southern Goodradigbee Inlet NW of Wee Jasper (Lindley 2002b) allowed recognition there of four of the limestone members forming the lower Taemas Limestone in the Taemas–Good Hope area. The upper part of the Taemas Limestone in this western area (Warroo and Crinoidal Limestone Member equivalents) is represented by a reef facies.

From unspecified horizons in the Taemas Limestone, Ross (1961) described the bryozoans

Cyphotrypa murrumbidgensis, *Stereotoechus shearsbyi*, *Leptotrypa* sp. A, *Homotrypa*? sp. B and *Ikelarchimedes warooensis* (from Por. 208, Parish of Warroo – possibly in the Receptaculites Limestone Member), and Bassler (1939) described the new species *Hederella browni*.

Spirifer yassensis Limestone Member (Dmts on Fig. 2)

The famous palaeontological heritage site known as 'Shearsby's Wallpaper' (Cramsie et al. 1978: photos 9 and 10) was named for the avid amateur fossil collector and geologist A.J. Shearsby. It occupies a cutting on the old coach road leading down to the crossing of the Murrumbidgee River (now submerged by Lake Burrinjuck) downstream from Taemas Bridge. The cutting exposes numerous steeply-dipping bedding planes in the lower Spirifer yassensis Limestone Member that are covered in fossils of the brachiopod *Spinella yassensis*, previously referred to *Spirifer* prior to revision by Strusz, Chatterton and Flood (1970), together with the chonetid brachiopod *Johnsonetes culleni* (Dun, 1904) redescribed by Strusz (2000). Other brachiopods recognised by Chatterton (1973) include *Athyris waratahensis*, *Howittia howitti* and "*Howittia*" *multiplicata*.

Also found at 'Shearsby's Wallpaper' and its immediate vicinity were two almost complete skulls of the primitive lungfish *Dipnorhynchus sussmilchi*, including the holotype (Etheridge 1906; Hills 1933, 1941; Campbell 1965; Thomson and Campbell 1971; Campbell and Barwick 1982), an incomplete placoderm skull described by Young (1985) as *Shearsbyaspis oepiki*, and isolated trunk-shield plates of the petalichthyid *Lunaspis* sp. Fossil fish described from elsewhere in the Spirifer yassensis Limestone Member include the acanthodian (ischnacanthid) *Taemasacanthus erroli*, *Ligulalepis toombsi*, and species of *Ohioaspis*, *Ohiolepis*, and *Onychodus* described by Schultze (1968). Basden (2003) illustrated a scale of *Gomphonchus*? *bogongensis* and a fragment of a platelet of *Lunaspis* sp. from this level. Placoderms described by Young (1981, 2004b, 2005) from the Spirifer yassensis Limestone Member in the Goodradigbee Valley, north of Wee Jasper, include *Arenipiscis westolli*, *Cavanosteus australis* and *Bimbianga burrinjuckensis*; *Cavanosteus australis* also occurs at this level at 'Shearsby's Wallpaper'. The arthrodire *Parabuchanosteus murrumbidgeensis*, described by White and Toombs (1972) from the Spirifer yassensis Limestone Member and younger units of the Taemas Limestone, was synonymised with *Buchanosteus confertituberculatus* by Young (1979). From a similar horizon at Wee Jasper, Long et al. (2014) described the buchanosteoid placoderm *Richardosteus barwickorum*.

Sherrard (1967) described the tentaculitids *Tentaculites chapmani* and *Nowakia* aff. *N. acuaria* from this locality. Probably this was also the site from which the ostracod *Primitia yassensis*, described by Chapman (1914) was collected by A.J. Shearsby; Chapman noted the locality in Portion 65, Parish of Taemas, as the "Cavan cutting" and mentioned associated specimens of the brachiopod *Chonetes culleni*, now *Johnsonetes culleni*.

Undescribed nautiloids recognised in this unit by Browne (1959) include *Pectinoceras*, *Buchanoceras*, *Macrodomoceras* and *Polyelasmoceras*?, comparable at species level with those described by Teichert and Glenister (1952) from other Lower Devonian limestones in eastern Australia.

Conodonts from the Spirifer yassensis Limestone Member belong to the *dehiscens* Zone of the earliest Emsian, which commences in the upper Cavan Bluff Limestone. Species recognised (Basden 2003) include *Polygnathus nothoperbonus, Oulodus murrindalensis, Ozarkodina buchanensis, Oz. linearis, Oz. prolata,* and *Pandorinellina exigua exigua*.

Currajong Limestone Member (Dmtc on Fig. 2)

Species of conodonts identical to those in the underlying Spirifer yassensis Limestone Member continue into the Currajong Limestone Member, implying that the latter is of *dehiscens* Zone age (earliest Emsian) for almost all its stratigraphic thickness. However, the uppermost beds may be of the succeeding *perbonus* Zone age (Basden 2003).

Coral fauna D of Philip and Pedder (1967), equivalent to the *Chalcidophyllum recessum* teilzone of Pedder (in Pedder et al. 1970), ranges through the Currajong Limestone Member, with specimens of this rugosan particularly abundant in bands in the lower part. *Embolophyllum asper* is associated with *C. recessum* only in the lowermost beds of this unit in the Wee Jasper area. The tabulate coral *Syringopora speleanus*, described by Etheridge (1902), is also present in the lower part of the member.

Burrow (2002) described acanthodian fish scales from the Currajong Limestone Member, including *Nostolepis* sp. cf. *N. taimyrica*, *Cheiracanthoides* sp. cf. *C. comptus*, *Gomphonchus*? *fromensis*, and *Gomphonchus*? *bischoffi*. Jawbones of two new species of acanthodian (ischnacanthid) fish *Taemasacanthus narrengullenensis* and *T. cooradigbeensis*, associated with *T.* cf. *erroli* Long, were described by Lindley (2002a) from two levels within the Currajong Limestone Member near Good Hope and in the Goodradigbee Valley. A new genus and species of

dipnoan (lungfish), *Cathlorhynchus trismodipterus*, was described by Campbell et al. (2009) from the basal Currajong Limestone Member in the Wee Jasper area. In the Taemas area, another dipnoan named *Dipnorhynchus kurikae* occurs in the upper half of this unit (Campbell and Barwick 1985).

<u>Bloomfield Limestone Member</u> (Dmtb on Fig. 2)

Conodont faunas from the Bloomfield Limestone Member are predominantly of *perbonus* Zone (early Emsian) age, although there is some possibility that the lowermost beds of the unit are of *dehiscens* Zone (earliest Emsian) age (Basden 2003).

No corals have been described from this level in the Taemas–Good Hope region of the eastern part of Burrinjuck Reservoir, but *Embolophyllum aggregatum aggregatum* occurs in the Bloomfield Limestone Member in the Goodradigbee Valley north of Wee Jasper (Pedder et al. 1970). The tabulate coral *Desmidopora nicholsoni*, described by Etheridge (1902) from Cave Flat (now Cave Island) at the former confluence of the Goodradigbee and Murrumbidgee rivers, probably also comes from this unit.

Fish are represented in this unit in the Taemas – Good Hope area and in the Goodradigbee Valley by the dipnoans *Dipnorhynchus sussmilchi*, *D. kurikae* and *Speonesydrion iani* (Campbell et al. 2000, 2009) and the acanthodian (ischnacanthid) *Taemasacanthus narrengullenensis* (described by Lindley 2002a). From a level correlated with the upper Bloomfield Limestone Member at Goodradigbee Inlet, Young (2004a, 2009) described the new arthrodire taxa *Cathlesichthys weejasperensis*, *Dhanguura johnstoni*, *Elvaspis tuberculata* and *E. whitei*. *Brindabellaspis stensioi* Young, 1980, an acanthothoracic placoderm, is likely from this level or the slightly younger Receptaculites Limestone Member.

Johnston (1993) described numerous bivalves from the uppermost Bloomfield Limestone Member (his localities R1a and R4), transitional in the case of R1 into the overlying Receptaculites Limestone Member. This interval may correspond in other areas of the Taemas Limestone succession to the newly recognised Cockatoo Point Limestone Member. Bivalves found in the Bloomfield Limestone Member include: *Nuculites* sp., *Nuculopsis* sp., *Mytilarca bloomfieldensis*, *Cornellites cattellus*, *C. campbelli*, *Limoptera murrumbidgeensis*, *Tolmaia erugisulca*, *Actinopteria* cf. *A. murrindalensis*, *Pseudaviculopecten etheridgei*, *Phorinoplax striata*, *Nargunella comptorae*, *Goniophora pravinasuta*, *G. duplisulca*, *Cypricardinia sinuosa*, *Sanguinolites*? *phlyctaenatus*, and *Eoschizodus taemasensis*. All these species apart from *P. etheridgei* were newly recognised by Johnston (1993).

<u>Cockatoo Point Limestone Member</u> (Dmtk on Fig. 2)

As this stratigraphic name has only recently been introduced in the Taemas – Good Hope area (Thomas and Pogson 2012), there has not been a long history of its use in published palaeontological descriptions. The dipnoans [lungfish] *Dipnorhynchus kurikae*, described by Campbell and Barwick (1985) from the vicinity of Cave Island in Burrinjuck Reservoir (collected when the water level was low), and *Speonesydrion iani* (see Campbell and Barwick 1983, 1984, 2007) obtained from limestone in the Goodradigbee Valley near Wee Jasper, potentially come from an equivalent level in the western area of outcrop of the Taemas Limestone, where they occur in the transition between the Bloomfield and Receptaculites limestone members of this area.

<u>Receptaculites Limestone Member</u> (Dmtr on Fig. 2)

Large specimens of the postulated dasycladacean alga *Receptaculites australis* are (or were – many having been removed by collectors) characteristic of this unit and give the member its name. They were first described from “Humewood” property by Etheridge and Dun (1898). However, not all of the type material they illustrated belongs to *R. australis*; as pointed out by Byrnes (1968), one example of another Early Devonian receptaculitid, *Ischadites struszi* that is preserved in matrix typical of the Garra Formation from the Wellington Caves district, was mistakenly included with the Burrinjuck specimens.

The sponge *Devonospongia clarkei*, redescribed by Howell (1957) and Pickett (1969), occurs in this limestone; it is one of the few fossils from the Murrumbidgee Valley that is recognisable from the monographic study by de Koninck (1876-1877) based on collections made by W.B. Clarke that were destroyed in the Garden Palace fire of 1882.

According to Chatterton (1973), the rugose coral *Xystriphyllum mitchelli* is found in biostromal bands or lenses about 60 m above the base of the Receptaculites Limestone Member rather than occurring at the base as claimed by Browne (1959). Hill (1941) described “*Cystiphyllum*” cf. *americanum* from the Receptaculites Limestone Member near Taemas Bridge; that coral was referred to an indeterminate species of *Plasmophyllum* by Pedder (in Pedder et al. 1970). Occurrence of this coral in the Taemas succession provides an important tie-point to the section in the Goodradigbee Valley described by Pedder et al., where it is found associated with *X. mitchelli* in the *Vepresiphyllum falciforme* zone.

Although Browne (1959) noted that the Spirifer yassensis Limestone Member was probably the source

of the tabulate coral described by Etheridge (1920) as *Columnopora* (*Gephuropora*) *duni*, Etheridge's own description suggested that this coral came from "near the Sponge Limestone, from which it may have been derived" which implies that the original level was the Receptaculites Limestone Member. This coral is now regarded as a species of *Favosites* with unusual morphological features interpreted as commensal worm tubes; Pickett (2010) noted that this association was described by Sokolov (1948) as *Phragmosalpinx australiensis*.

Trilobites described by Chatterton (1971) from his locality A on the boundary between the Receptaculites Limestone Member and Warroo Limestone Member have been subsequently revised, with current determinations including *Cyphaspis dabrowni* redescribed by Adrain and Chatterton (1996), *Ceratocephalina vexilla* revised by Ramsköld (1991), *Kettneraspis clavata* reassigned by Ramsköld and Chatterton (1992), and *Maurotarion struszi* revised by Adrain and Chatterton (1995). Edgell (1955) described *Acanthopyge (Mephiarges) bifida*, subsequently referred by Temple (1972) to *Acanthopyge (Jasperia)*, from probably an equivalent level in the Goodradigbee Valley sequence.

Brachiopods in this unit tend to be concentrated at certain levels where silicification was optimal. The lower part of the member on "Bloomfield" property at the eastern side of Lake Burrinjuck near Taemas Bridge is the type locality for *Malurostrophia flabellicauda* Campbell and Talent, 1967. The majority of the brachiopod fauna was described by Chatterton (1973) mostly as new species, although some identifications have since been revised or reassigned by Talent et al. (2001:160). From the lower part of the Receptaculites Limestone Member, Chatterton described *Craniops australis*, *Salopina kemezysi*, *Cymostrophia dickinsi* [=*Mesodouvillina* (*Protocymostrophia*) *dickinsi*], *C. multicostella*, *Malurostrophia flabellicauda*, *M. flabellicauda reverta* [=*Malurostrophia flabellicauda s.s.*], *Leptostrophia clarkei*, *Schuchertella murphyi*, *Parachonetes flemingi* and *P. konincki* [both species redescribed by Strusz 2000], *Protochonetes culleni* [now *Johnsonetes culleni*, redescribed by Strusz 2000], *Ambothyris runnegari*, *Coelospira dayi*, *Atrypa penelopeae*, *Anatrypa erectirostris*, *Athyris waratahensis*, *Cyrtina* aff. *C. wellingtonensis*, *Howittia howitti*, *H. multiplicata*, *Spinella yassensis*, *Quadrithyrina allani*, *Howellella* aff. *H. textilis*, *Hysterolites* sp., *Callipleura*? sp., *Eoglossinotoechia linki*, *Adrena expansa*, *Cydimia robertsi*, *C. parva*, and *Micidus shandkyddi*.

With the exception of *Mesodouvillina* (*Protocymostrophia*) *dickinsi*, *Hysterolites* sp., *Callipleura*? sp., *Cydimia robertsi* and *C. parva*, all of the above brachiopod species are also represented in Chatterton's Assemblage A from the top of the Receptaculites Limestone Member, with the addition of the following species: *Aulacella stormeri* [=*Dalejina philipi*, according to Talent et al. (2001:160)], *Malurostrophia flabellicauda* [synonymised by Talent et al. with Chatterton's *M. flabellicauda reverta*, *M. minima* and *M. aura*], *Spinulicosta campbelli*, *Cyrtinopsis* aff. *C. cooperi* [=*Plicocyrtina crenulata* Gratsianova and Talent], *Delthyris hudsoni*, *Browneella browneae*, *Pugnax oepiki*, *Adrena cernua* [synonymised with *A. expansa* by Talent et al.], and *Micidus*? *glaber*. *Johnsonetes latus* from this level was revised by Strusz (2000).

Reynolds (1978) documented a diverse fauna of ostracodes (22 genera and 33 species, 21 of which were new) from the Receptaculites Limestone Member. These included *Renibeyrichia pulcher*, *R. pustulosa*, *Thuringobolbina australis*, *Acinacibolbina anteropinnata*, *Subligaculum*? sp. A., *Nezamyslia carinata*, *Gyrgathella garryi*, *Cavanites robustihamatus*, *C. minilobatus*, *Hanaites* sp. A, *Hyperchilarina devonica*, *Libumella follis*, *Berounella verrrucosa*, *B. thymosa*, *B. trifolispina*, *B. spinosa*, *B.* sp., *Tricornina robusticerata*, *Coniferina humensis*, *Bairdiocypris reynoldsi*, *B. astalis*, *Praepilatina* sp. A., *Tubulibairdia tumida*, *Newsomites dorsennus*, *Acanthoscapha brevicristata*, *A.* aff *A. laterispina*, *Cavellina* sp., *Batalaria epicopella*, *Risboa sarculina* and *Ampuloides* sp. A., together with several indeterminate forms.

Tassell (1980, 1982) described gastropods from this unit, the majority of which were recognized as new species. The fauna includes *Ptychosphaera convolutus*, *Coelocyclus hadroni*, *Tropidodiscus centrifugalis*, *Retispira retifera*, *Straparollus* (*Euomphalus*) *leptoni*, *Straparollus* (*Serpulospira*?) sp., *Arizonella*? *conoidea*, *Mourlonia subglobosa*, *Oehlertia pioni*, *Bembexia micula*, *Bembexia* sp., *Hesperiella* sp., *Umbotropis mesoni*, *Coelozone*? sp., *Trochonema* sp., *Trochonema*? *nodosa*, *Holopea protoni*, *Platyceras* (*Platyceras*) sp. A, *Platyceras* (*Platyceras*) sp. B, *Naticopsis* (*Naticopsis*) *taemasensis*, *Murchisonia* (*Murchisonia*) *turris*, *Murchisonia* (*Murchisonia*) *fermioni*, *Murchisonia* (*Ostioma*) *bloomfieldia*, *Mesocoelia quarki*, *Michelia darwini*, *Stegocoelia* (*Stegocoelia*) *bononi*, *Taemasotrochus giganticus*, *Mitchellia striatula*, *Loxonema altacostatum*, *Palaeozygopleura muoni*, *Hemizyga* (*Hyphantozyga*) *granifera*, *Subulites* (*Fusispira*) sp., *Leptoptygma australe*, and *Ianthinopsis ornatus*.

Johnston (1993) described a very diverse bivalve fauna (dominated by new species) from the lower

part of this unit, including *Polidevcia* cf. *P. insolita*, *Deceptrix*? *clarkei*, *Nuculites* sp., *Nuculopsis* sp., Solemyidae sp. indet., *Mytilarca bloomfieldensis*, Rhombopteriidae gen et sp. nov., *Cornellites cattellus*, *C. campbelli*, *C. talenti*, *Limoptera murrumbidgeensis*, *Tolmaia erugisulca*, *Actinopteria* cf. *A. murrindalensis*, *Pseudaviculopecten etheridgei*, *Phorinoplax striata*, *Nargunella comptorae*, *Goniophora pravinasuta*, *G. duplisulca*, *Cypricardinia sinuosa*, *Sanguinolites*? *phlyctaenatus*, *Cimitaria*? sp., *Grammysioidea* sp., *Eoschizodus taemasensis*, *Schizodus truemani*, *Paracyclas proavia*, *P. rugosa*, *P. alleni*, and *Crassatellopsis lenticularis*. From the top of the Receptaculites Limestone Member, Johnston recorded the bivalves *Deceptrix*? *clarkei*, *Nuculites* sp., Solemyidae sp. indet., *Mytilarca bloomfieldensis*, Rhombopteriidae gen et sp. nov., *Cornellites cattellus*, *Goniophora duplisulca*, *Cypricardinia sinuosa*, *C. minima*, *Eoschizodus taemasensis*, *Schizodus truemani*, *Paracyclas rugosa*, and *Crassatellopsis lenticularis*.

Campbell and Barwick (1985, 2000) described the dipnoan *Dipnorhynchus kurikae* from the Receptaculites Limestone Member in the Goodradigbee Valley. The placoderm *Murrindalaspis wallacei* was described from this level both at Taemas and in the Goodradigbee area by Long and Young (1988). Giffin (1980) documented the following vertebrate microfauna from the lower 65 m of the Receptaculites Limestone Member: *Skamolepis fragilis*, *Ohioaspis tumulosa*, *Ohiolepis* sp., *Cheiracanthoides comptus*, an indeterminate acanthodian spine, *Onychodus*? *sigmoides*, *Onychodus*? sp. teeth, *Ligulalepis toombsi*, and paleoniscoid scales. Further acanthodian fish scales including *Nostolepis* sp. cf. *N. taimyrica* and *Gomphonchus*? *fromensis* were described by Burrow (2002). Basden (2003) illustrated *Cheiracanthoides* sp. cf. *C. wangi* and ischnacanthid scales from this level at Taemas, and a scale of *Murrindalaspis* from the Receptaculites Limestone Member at Wee Jasper. New taxa of brachythoracid placoderms described from this area by Young (1981) include *Arenipiscis westolli* and *Errolosteus goodradigbeensis*.

Bryozoa are represented in the Receptaculites Limestone Member by *Semicoscinium vallatum* and possibly also by *Ikelarchimedes warooensis*, described by Crockford (1941) and Ross (1961), respectively.

Tentaculites chapmani, described by Sherrard (1967) from Portion 208, Parish of Warroo, downstream from Taemas Bridge on the north bank of the Murrumbidgee River opposite 'Shearsby's Wallpaper', may also come from this level.

The age of the Receptaculites Limestone Member, based on conodonts, is early Emsian (*perbonus* Zone) (Basden 2003).

Warroo Limestone Member (Dmtw on Fig. 2)

The Warroo Limestone Member also yields conodonts of *perbonus* Zone age (early Emsian), possibly extending into the overlying *inversus* Zone in the uppermost beds (Lindley 2002b, Basden 2003).

Brachiopods described by Chatterton (1973) from this unit in the Taemas area include *Craniops australis*, *Isorthis spedeni*, *Resserella careyi*, *Muriferella hillae* [=*M. punctata*, according to Talent et al. 2001], *Aulacella philipi* and *A. stormeri* [both assigned to *Dalejina philipi* by Talent et al.], *Cymostrophia dickinsi*, *Taemostrophia patmorei*, *Malurostrophia minima* and *M. bella* [both assigned to *Malurostrophia flabellicauda* by Talent et al.], *Leptostrophia clarkei*, *Schuchertella murphyi*, *Parachonetes konincki*, *Spinulicosta campbelli*, *Ambothyris runnegari*, *Coelospira dayi*, *Cyrtina* aff. *C. wellingtonensis*, *Howittia howitti*, *Hysterolites* sp., *Delthyris hudsoni*, *Eoglossinotoechia linki*, *Pugnax oepiki*, *Adrena cernua* [synonymised with *A. expansa* by Talent et al.] and *Micidus shandkyddi*. Campbell and Chatterton (1979) further documented *Coelospira dayi*, and Strusz (2000) revised *Johnsonetes latus* (from the lower part of the unit) and *Septachonetes melanus*.

The only trilobite described from this level (Chatterton et al. 1979) is *Acanthopyge* (*Lobopyge*) sp.

Johnston (1993) described bivalves, mostly new species, from the lower to middle part of the Warroo Limestone Member, including *Polidevcia* cf. *P. insolita*, *Deceptrix*? *clarkei*, *Nuculites* sp., *Mytilarca bloomfieldensis*, Rhombopteriidae gen et sp. nov., *Cornellites cattellus*, *Goniophora duplisulca*, *Cypricardinia sinuosa*, *C. minima*, *Eoschizodus taemasensis*, *Paracyclas rugosa*, *Crassatellopsis lenticularis*, and *C. yongei*.

Fish remains from the Warroo Limestone Member were compared by Findlay (1996) to *Arenipiscis westolli*. Lindley (2002b) documented the acanthodian *Taemasacanthus narrengullenensis* and fragmentary ischnacanthid material including jawbones and scales, together with *Cheiracanthoides comptus* and a new species of *Onychodus*, *O. yassensis*.

Crinoidal Limestone Member (Dmtn on Fig. 2)

Basden (2003) assigned an *inversus* and *serotinus* Zone age (middle to late Emsian) to the Crinoidal Limestone Member. However, evidence for conodonts

characteristic of the *inversus* Zone age is minimal and that zone may be absent, due to a disconformity between the Warroo Limestone Member and the Crinoidal Limestone Member (Chatterton 1973).

Findlay (1996) described fish fossils from this unit in the Taemas area, including cf. *Errolosteus goodradigbeensis*, cf. *Arenipiscis westolli,* and cf. *Parabuchanosteus murrumbidgeensis*. Other fish have been described from laterally equivalent strata near the top of the Taemas Limestone exposed in the Goodradigbee Valley, north of Wee Jasper. These include a new species of petalichthyid placoderm described by Young (1978) as *Wijdeaspis warrooensis*, and a new species of the dipnoan (lungfish) *Dipnorhynchus*, *D. cathlesae*, described by Campbell and Barwick (1999). The latter was collected approximately 197 m below the base of the Hatchery Creek Group, at a level probably equivalent to the Crinoidal Limestone Member, though lacking the distinctive crinoidal fauna associated with that unit. Immediately beneath the Hatchery Creek Group, Campbell and Barwick identified a white, thin-bedded limestone 69 m thick and commonly cross-bedded, which they interpreted as having been deposited in the intertidal zone. Only ptyctodont fish teeth, together with rare fragmentary macrofossils, are present in this limestone, which they imply is transitional between the underlying marine limestones and the overlying fresh water clastic-dominated sediments forming the Hatchery Creek Group.

Hatchery Creek Group

Corradigbee Formation (Dyc on Fig. 2)

Outcrop of the Hatchery Creek Group is largely confined to the Brindabella 1:100,000 mapsheet, where it is bounded by the Goodradigbee Valley to the east, the Burrinjuck Granite to the west, and Burrinjuck Reservoir to the north. Two formations have been recognised in this area by Hunt and Young (2010) – the Wee Jasper Formation (Dyw on Fig. 2, including conglomeratic and sandstone facies) in the lower part, overlain by the finer-grained Corradigbee Formation.

Young and Gorter (1981) described a fish fossil fauna from calcareous nodular mudstone at least 1500 m above the base of the clastic-dominated non-marine sequence that conformably overlies limestones of the Murrumbidgee Group (Taemas Limestone). This locality is now regarded as lying within the Corradigbee Formation. The diverse fauna (with updated identifications, from Hunt and Young 2010, 2011 and additional material figured in Young et al. 2010) includes the thelodontid *Turinia*? cf. *T. hutkensis*; acanthodians: climatiid gen. et sp. indet., diplacanthiform? gen. et sp. indet., *Tareyacanthus* cf. *T. magnificus* and *Watsonacanthus*? sp.; sarcopterygians: *Gyroptychius*? *australis*, two new taxa of osteolepiforms, and an indeterminate onychodontid?; arthrodire placoderms: *Denisonosteus weejasperensis*, cf. *Denisonosteus* sp. nov., cf. *Coccosteus* sp., and *Edgellaspis gorteri* (a new arthrodire described by Hunt and Young 2011); and the antiarch placoderms *Sherbonaspis hillsi*, cf. *Sherbonaspis* sp. nov., and *Monarolepis verrucosa*. An early Middle Devonian (early to mid Eifelian) age is now ascribed to this fauna, which is designated macrovertebrate (MAV) assemblage 3 in the scheme proposed by Young (1993, 2007).

EARLY DEVONIAN STRATIGRAPHY AROUND WINDELLAMA

Bindook Group

Tangerang Formation (Dkt on Fig. 2)

Jones et al. (1986) illustrated a variety of macrofossils from the lower part of the Tangerang Formation including the encrusting tabulate coral *Pleurodictyum* sp., brachiopods cf. *Nucleospira* sp. and cf. *Salopina* sp., and trilobites including cf. *Lioharpes* sp., *Crotalocephalus*? sp., *Acanthopyge*? (*Lobopyge*) sp., fragmentary proetid, scutellid and odontopleurid remains, together with the new species *Ananaspis ekphyma*. Although this fauna lacks precise age connotations, the stratigraphic correlation suggested by Jones et al. with the middle Windellama Limestone Member implies a Lochkovian age, based on the conodonts described by Mawson (1986).

Mawson and Talent (1999) described the brachiopod *Aulacella* sp. from the Tangerang Formation above the Windellama Limestone Member, and noted the occurrence of *Howellella* sp. and an indeterminate rhynchonellid from this level. Mawson (1975) listed the corals *Pleurodictyum megastoma*, *Cladopora* cf. *C. corrigia* and *Syringaxon* sp., bryozoans *Fenestella* sp. nov., *F. dargonensis* and an indeterminate trepostome, and a trilobite fauna including *Koneprusites* sp., *Acanthopyge australis*, *Leonaspis* sp., *Phacops* sp., scutellids, and *Cheirurus* (*Crotolocephalides*) *gaertneri* that suggests a Pragian age for a level about 375 m above the base of the Tangerang Formation.

Limestones in the Tangerang Formation that yield a Windellama-type conodont and fish fauna were almost certainly derived from the upper Windellama Limestone Member, which was the only level to yield fish remains (Basden et al. 2000). Other limestone pods in the Tangerang Formation, which lacked this

distinctive association, may have had a different provenance.

Windellama Limestone Member (Dktw on Fig. 2)

[Note that Ruth Mawson, John Talent and their colleagues from Macquarie University, who have studied the Windellama area in great detail over the past four decades, refer to this unit in their publications as a formation, rather than a member].

Mawson (1986) documented a sparse conodont fauna from the lower 128 m of the Windellama Limestone Member. She ascribed to this fauna a Pridolian (*eosteinhornensis* Zone) age on the basis of a single poorly preserved juvenile Pa element assigned to *Ozarkodina remscheidensis eosteinhornensis*; the other three specimens recovered (but not illustrated) from this interval are of no assistance in confirming the Pridolian age. The conodont fauna from the upper Windellama Limestone Member is much more diverse, with several age-diagnostic species. Conodonts described by Mawson from the upper 161 m of this unit include *Amydrotaxis corniculans*, *A. johnsoni*, *Belodella devonica*, *B. triangularis*, *B. resima*, *Icriodus postwoschmidti*, *Oulodus greilingi spinosus*, *O. greilingi hirpex*, *O. aclys*, *O. spicula*, *O. tenustriata*, *O. walliseri*, *O.* sp., *Ozarkodina parvidentata*, *Panderodus unicostatus*, *Pedavis*? sp., *Wurmiella excavata excavata*, *W. excavata emaciata*, and *Zieglerodina remscheidensis remscheidensis*. Mawson determined that this upper part of the Windellama Limestone Member spans the *postwoschmidti*/*eurekaensis* and *delta* zones of the early to middle Lochkovian (earliest Devonian). The uppermost limit of the Windellama Limestone Member is more contentious. Although Mawson suggested that the top of the unit may range as high as *pesavis* Zone, the evidence quoted in support of this relies on a new species of *Ozarkodina* (*O. parvidentata*) – which, as far as we are aware, is not known in sequence elsewhere locally – and a fragment of a Pa element "referred to *Pedavis* sp. somewhat hesitantly" (Mawson 1986:45) that elsewhere in this paper is termed cf. *Pedavis* sp. or *Pedavis*? sp. The range of *Pedavis* is, however, not restricted to the *pesavis* Zone (latest Lochkovian); the genus first appears in the late Ludlovian, and the species *P. pesavis* extends through both its nominate zone and the underlying *delta* Zone, according to Sweet (1988, Appendix B, Chart 4). Furthermore, *Zieglerodina remscheidensis remscheidensis* occurs right to the top of the QU section at Windellama; both Sweet (1988) and Mawson (1987) depict the range of this species as extending no higher than the top of the *delta* Zone. On balance, the conodont evidence supports an age range of probably Pridolian to the top of the mid Lochkovian *delta* Zone for the Windellama Limestone Member in its type area. A *delta* zone conodont assemblage recovered from near the base of the Windellama Limestone Member (Percival and Sherwin 2008) in the Braidwood district, implies that the base of this unit is markedly diachronous.

Mawson and Talent (1999) described the following rhynchonelliform brachiopods (predominantly new taxa) from the Windellama Limestone Member: *Schizophoria antiqua erugata*, *Isorthis* cf. *I. clivosa*, *Pelecymya caperata*, *Pelecymya*? sp., *Mesodouvillina* (*Protocymostrophia*) *torosa*, *Morinorhynchus trypeter*, *Asymmetrochonetes picketti*, *Gypidula pelagica lunata*, *Machaeraria formosa*, *Hadrorhynchia*? *attinarium*, *Sphaerirhynchia*? *mastodon*, *Atrypa nieczlawiensis*, *Ambothyris*? *inopsis*, *Howellella placeotextilis*, *H. alatextilis*, *H. legirupa*, *Reticulariopsis saginatus* and *Cyrtina praecedens*. Associated discinid and acrotretid brachiopods include *Schizotreta* sp. and *Opsiconidion* sp. (Brock et al. 1995).

Gastropods from the Windellama Limestone Member, mostly new species described by Mawson et al. (2002) include: *Bellerophon* sp., *Ruedemannia* (*Batteniella*) *calvata*, *Straparollus* (*Euomphalus*) sp., *Holopea*? sp., *Gyronema chico*, *Australonema parva*, *Yochelsonatia resticula*, *Murchisonia* (*Murchisonia*) *auctor*, *Domiporta laxa*, *Loxonema* sp., *Stylonema* sp., *Perneratia aristerospira*, *Subulites* (*Fusispira*) *aulakion* and *Vetotuba*? sp.

Bell et al. (2000) described the following agglutinated foraminifera from the Windellama Limestone Member: *Astrorhiza triquetra*, *Rhabdammina* sp. B, *Bathysiphon* sp., *Psammosphaera cava*, *P. aspera*, *Sorosphaera confusa*, *S. tricella*, *Stegnammina cylindrica*, *Stomasphaera cyclops*, *Hemisphaerammina crassa*, *Tolypammina anguinea*, *Ammovertella* sp., *Ammovolummina bostryx*, *Serpenulina uralica* and *S. aulax*.

Parkes (in Basden et al. 2000) illustrated representative microvertebrates (fish) from the upper 161 m (Lochkovian age) of the Windellama Limestone Member, including placoderms (a variety of scale types and bone fragments comprising buchanosteids, a possible weejasperaspid and an acanthothoracid), acanthodian remains such as scales of *Nostolepis*, scales and a tooth whorl of *Gomphonchus*?, and a dentition cone assigned to *Poracanthodes*.

Murruin Formation (Dkm on Fig. 2)

GSNSW conodont sample C2334 (Percival and Sherwin 2005) from limestone clasts in a conglomerate at the base of the Murruin Formation

in Cobra Creek produced 54 identifiable conodont elements, including three specimens of *Flajsella stygia*. This species has a very restricted range in the middle part of the Lochkovian Stage of the Early Devonian, equivalent to the upper half of the *delta* Zone. However, as this sample came from clasts it provides only a maximum age that may not necessarily reflect the true depositional age of the Murruin Formation.

EARLY DEVONIAN STRATIGRAPHY AROUND LAKE BATHURST

Mulwaree Group

Bongalaby Formation (Dwb on Fig. 2)

Etheridge (1881) first described fossils from Devonian limestone at 'Bungaralaby, Lake Bathurst', including a gastropod questionably referred to *Loxonema sulculosa*, and "a mutilated specimen of *Conocardium*". Fletcher (1943) assigned the latter specimen to *C. sowerbyi*, and also described and illustrated another specimen from Tarago, south of Lake Bathurst, which he designated as the neotype of that species, to replace de Koninck's specimens occurring in black argillaceous limestone from the "Yass district" (most probably Taemas), that were destroyed in the Garden Palace fire of 1882. Another species of *Conocardium, C. mundulum,* was described by Fletcher (1943) based on a single specimen collected from limestone at Lake Bathurst Railway Station. Ross (1961:18) recorded corals, the dasycladacean alga *Receptaculites australis* and the bryozoan *Hemitrypa* sp. A from this area. Pedder (in Pedder et al. 1970:235) noted the presence of the compound rugose coral *Hexagonaria smithi smithi* in Emsian limestone at the junction of Limestone and Bongaralaby creeks near Lake Bathurst Railway Station.

The occurrence of *Receptaculites australis* and *Hexagonaria smithi smithi* confirms the similarity in age between the limestones of the Lake Bathurst area and the Taemas Limestone of the Burrinjuck region. Conodonts recovered from limestones at several levels in the Bongalaby Formation (including the Lake Bathurst Limestone Member) during recent remapping of the Braidwood 1:100,000 mapsheet by the Geological Survey of NSW provide greater biostratigraphic precision in support of this correlation. However, in many cases, specific identifications are hindered by a combination of abrasion and fragmentation of conodont elements in a turbulent shallow marine environment, subsequent tectonic distortion and high CAI (5 or greater).

Lake Bathurst Limestone Member (Dwbl on Fig. 2)

Pa and Pb elements of a robust species of *Amydrotaxis*, close to *A. druceana*, were found in GSNSW conodont sample C2403 from the base of this unit. The Pa elements in particular appear to have been tumbled by wave or current action so that the denticles and lateral lobes of the basal cavity have been broken or eroded, thus preventing a definitive identification. Pickett (1980) noted that *A. druceana* ranged through both the *pesavis* and *sulcatus* zones of the latest Lochkovian to earliest Pragian. Elsewhere it apparently extends to the end of the Pragian (consistent with the range of the genus, which in NSW terminates in the *pireneae* Zone). GSNSW sample C2407, obtained from the upper part of the Lake Bathurst Limestone Member in the well-exposed and highly fossiliferous section along Bongalaby Creek, yielded a diverse and abundant fauna, including juvenile *Polygnathus dehiscens* or *P. perbonus*, *Ozarkodina buchanensis*, *Oz. linearis*, *Oulodus murrindalensis,* and either *Pandorinellina exigua* or *P. philipi.* This assemblage constrains the age of the sample to the *dehiscens* to *perbonus* zones of the early Emsian. The microfossils, which also include numerous fish scales and teeth, are generally broken and abraded. Burrow et al. (2010, fig. 5, K and L respectively) identified some of the acanthodian fish scales from this sample as *Cheiracanthoides wangi* and *Gomphonchus*? *bischoffi*. Macrofossils noted on the outcrop include the corals *Syringopora* and a very fine tabulate, possibly *Desmidopora.*

Ages of other limestones in the lower Bongalaby Formation are similar to the Pragian to early Emsian range established for the Lake Bathurst Limestone Member. In many samples, the presence of polygnathid conodont elements implies an age no older than late Pragian (*Polygnathus pireneae* Zone). The age of GSNSW sample C2526 can be restricted to the late Pragian to earliest Emsian interval (*pireneae* to *dehiscens* zones), based on the association of *Pandorinellina optima* with an undetermined polygnathid. Another sample, C2437 of comparable age, yielded specimens of *Polygnathus* (possibly *P. dehiscens*), and a few indeterminate elements of *Pandorinellina*, together with elements tentatively identified as *Ozarkodina buchanensis*.

Conodonts identified in GSNSW sample C2527 include *Panderodus unicostatus*?, *Belodella devonica*, *Pelekysgnathus* sp., *Polygnathus perbonus*, *Pandorinellina optima* or *P. prolata*, and *Pandorinellina exigua*. *Polygnathus perbonus* (also found in the lower Taemas Limestone) indicates an early Emsian (*P. perbonus*-*P. gronbergi* Zone) age, consistent with the ranges of the associated species that extend over neighbouring zones.

GSNSW conodont sample C2404 from the base of the upper limestone sequence in the Bongalaby Formation yielded a Pa element of *Pandorinellina exigua philipi*. Elsewhere in central NSW the range of this subspecies extends from the base of the *pesavis* Zone (late Lochkovian) to the *patulus* Zone at the top of the Emsian (Farrell 2003). Also recovered from the residue were a variety of unidentified fish scales.

A quite different clastic facies assigned to the Bongalaby Formation on the Braidwood 1:100,000 mapsheet (Fitzherbert et al. 2011), comprising reddish-purple siltstone to pale greenish grey silty mudstone, contains abundant fragmentary remains of a primitive terrestrial plant comparable with *Cooksonia* sp. This material consists of fragmentary bifurcating stems, ranging in width from 2mm to 5mm, although the width is uniform in individual fragments.

Ungrouped Devonian strata

Cunningham Formation, Copperhannia Member (Dxnc on Fig. 2)

GSNSW conodont sample C1768 was obtained from a thin-bedded calcarenite in the Copperhannia Member of the Cunningham Formation, on the Blayney 1:100,000 mapsheet (Percival 2000). Identifiable conodonts included Pa elements of *Zieglerodina remscheidensis* sensu lato, Pb and other elements assigned provisionally to *Wurmiella excavata*, *Oulodus* sp, and *Panderodus*? sp. The presence of *Z. remscheidensis* indicates a Pridoli (latest Silurian) to Early Devonian age.

LATE DEVONIAN

Lambie Group

Strathaird Formation (Dls on Fig. 2)

Samples of the Strathaird Formation that were processed for conodonts failed to yield any, the residue being dominated by eroded and polished lingulide brachiopod fragments. Probably this unit accumulated very near to the shoreline, where intertidal lingulide brachiopods were continually reworked in the swash zone. Presence of the brachiopod *Cyrtospirifer* in the Strathaird Formation is further indication of a marine incursion into the otherwise predominantly fluvio-lacustrine Lambie Group. Young (2007) recognised this maximum marine incursion within the Merimbula Group of the far South Coast (a correlative of the Lambie Group) as the Ettrema–Westwood transgression. In Ettrema Creek gorge on the Moss Vale 1:100,000 mapsheet, a comparable fauna with *Cyrtospirifer* is associated with limestone containing late Frasnian (*rhenana* or *gigas* Zone) conodonts (Pickett 1973). Conodont species present at Ettrema (identifications revised from form species described in the original report by Pickett) include *Ancyrodella curvata*, *Ancyrognathus asymmetricus*, *Apatognathus varians*, *Icriodus* sp., *Icriodus expansus*, *Palmatolepis hassi*, *Pelekysgnathus* cf. *P. planus*, *Polygnathus webbi* and *Polygnathus ettremae* [also referred to *Uyenognathus wadleighensis* by Savage 2004].

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Appendix

Notes on Silurian conodonts
(Y.Y. Zhen)

Kockelella sp. cf. *K. variabilis* Walliser, 1957
Fig. 4a-b

Material

A single specimen of a Pa element, from an allochthonous limestone in the Hawkins Volcanics (GSNSW conodont sample C1862), exposed in a creek east of Meringullalong locality, about 11 km NE of Boorowa and 13.5 km south of Frogmore (GR 668193 6193200, Boorowa 1:100,000 mapsheet).

Remarks

Two subspecies of *Kockelella variabilis* have been described: *K. variabilis variabilis* Walliser, 1957 and *K. variabilis ichnusae* Serpagli and Corradini, 1998. The Pa element of *K. variabilis variabilis* has a wider and branched inner-lateral process, from which the Pa element of *K. variabilis ichnusae* is mainly differentiated by having a wider platform with a distinctive rim and an unbranched inner-lateral process. The Pa element documented here has a wide platform and an unbranched inner-lateral process similar to the subspecies *ichnusae*, but the platform lacks the characteristic rim of that form, and the inner-lateral process is longer and narrower and differs from the holotype of *K. variabilis ichnusae* in bearing three denticles. It may represent a new subspecies, but given that only a sole specimen is presently known it is designated as *K.* sp. cf. *K. variabilis*. Serpagli and Corradini (1999) suggested an age range for *K. variabilis* extending from the late *K. crassa* Biozone (earliest Gorstian) to high in the Ludlow (basal *Polygnathoides siluricus* Biozone). However, *K. variabilis variabilis* was more recently reported from the lower Wenlock in Tibet (Wang, 2013:159-160, pl. 61, fig. 6) and *K. variabilis ichnusae* from the uppermost Wenlock of South China (Wang, 2013:160, pl. 61, figs 9-10). In New South Wales, both subspecies of *K. variabilis* were previously reported from the Bowspring Limestone Member (Ludlow, *Ancoradella ploeckensis* Biozone) and Hume Limestone Member (Ludlow, top *A. ploeckensis* Biozone to basal *P. siluricus* Biozone) of the Silverdale Formation in the Yass Basin (Link and Druce, 1972:41, pl. 3, figs 11, 12, 15, 16, text-fig. 21 (*K. v. ichnusae*); pl. 4, figs 1, 4, 5 (*K. v. variabilis*)).

Panderodus sp. nov.
Fig. 6a-s

Material

15 specimens from GSNSW conodont sample C1985 (allochthonous limestone block probably in the Kerrawarry Formation), from abandoned limestone quarry at Jerrara Creek, approximately 6 km NW of Bungonia (GR 765575 6144050, Goulburn 1:100,000 mapsheet); three specimens from GSNSW conodont sample C1862 (allochthonous limestone in the Hawkins Volcanics), from limestone block exposed in a creek east of Meringullalong locality, about 11 km NE of Boorowa and 13.5 km south of Frogmore (GR 668193 6193200, Boorowa 1:100,000 mapsheet).

Description

A species of *Panderodus* consisting of short-based Pa and Pb elements and long-based S elements with Sb, Sc and Sd elements recognized; all elements with a deep panderodid furrow on the outer-lateral face, pronounced basal wrinkles, and a posteriorly extended base, which is more or less triangular in outline in lateral view. Pa element (Fig. 6k-l) with a basally suberect and distally reclined cusp, and a short and posteriorly extended base, cusp moderately compressed laterally, biconvex, with sharp posterior margin, a narrow and inner-laterally slightly flexed anterior margin, a deep and narrow furrow on the outer-lateral face (Fig. 6k) and a broad weak carina on the inner-lateral face (Fig. 6l); base with a straight to gently arched upper margin and a straight to slightly curved basal margin, tapering posteriorly. Pb element (Fig. 6d-e) with an erect cusp and a short base; cusp biconvex in cross section with a sharp posterior margin, a deep and narrow furrow on the outer-lateral face (Fig. 6d-e) and a less convex inner-lateral face; base extended posteriorly, triangular in outline with straight basal and upper margins. Sb element (Fig. 6f-g, n-p) laterally compressed with a long base; cusp suberect and biconvex with a sharp posterior margin and a deep and narrow furrow on the more convex outer-lateral face. Sc element (Fig. 6j, m) strongly compressed laterally with a suberect cusp and a long and posteriorly extended base; cusp with sharp anterior and posterior margins, a flat (Fig. 6m) or less convex (Fig. 6j) inner lateral face, and a furrowed and more convex outer-lateral face; anterior margin often flexed inward (Fig. 6m); base triangular in outline with a straight upper margin and a slightly curved basal margin. Sd element (Fig. 6a-c, h-i, q-s) like Sb, but with cusp distally twisted inward.

Discussion

This species differs from other known species of *Panderodus* by having a prominent posterior extension of the base particularly in the Pa and Pb elements (Fig. 6d-e, k-l). The Pb element is comparable with the M element of *Panderodus spasovi* Drygant, 1974 documented by Barrick (1974, pl. 3, fig. 13) from the upper Llandovery of Oklahoma, but other elements in the latter species lack extended bases.

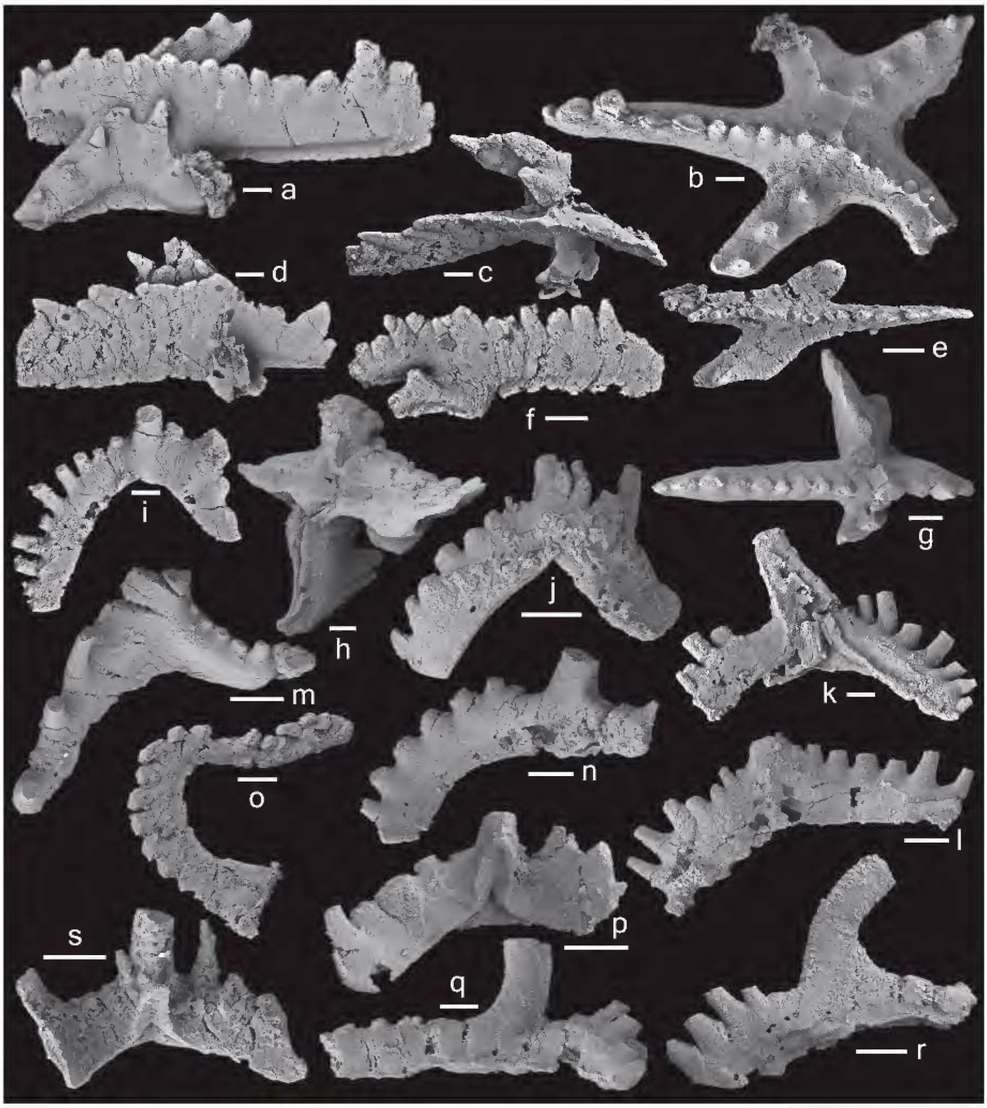

Figure 4. **a-b, *Kockelella* sp. cf. *K. variabilis* Walliser, 1957; Pa element, MMMC5086, a, outer-lateral view (IY249-024), b, upper-view (IY249-002). c-h, *Kockelella maenniki* Serpagli and Corradini, 1998, Pa element, c-d, MMMC5087, c, upper view (IY249-005), d, inner-lateral view (IY249-025); e-f, MMMC5088, e, upper view (IY249-012), f, outer-lateral view (IY249-026). g, MMMC5089, upper view (IY276-020). h, MMMC5090, basal view (IY276-021). i-o, q-r, *Kockelella* sp. A; i-j, Sb element; i, MMMC5091, posterior view (IY249-018); j, MMMC5092, anterior view (IY276-018); k-n, Pb element; k, MMMC5093, basal-inner-lateral view (IY249-006); l, MMMC5094, outer-lateral view (IY276-013); m, MMMC5095, upper-inner-lateral view (IY276-014); n, MMMC5096, inner-lateral view (IY276-017); o, q-r, Sc element, o, MMMC5097, upper-posterior view (IY249-021). q, MMMC5098, inner-lateral view (IY276-015); r, MMMC5099, outer-lateral view (IY276-016). p, s, *Wurmiella excavata* (Branson and Mehl, 1933); p, Sb element, MMMC5100, posterior view (IY276-019); s, Sa element, MMMC5101, posterior view (IY277-027). a, b, from sample C1862 (limestone block in Hawkins Volcanics); all other specimens are from sample C1985 (allochthonous limestone block possibly within the Kerrawary Siltstone). Scale bar 100 µm.**

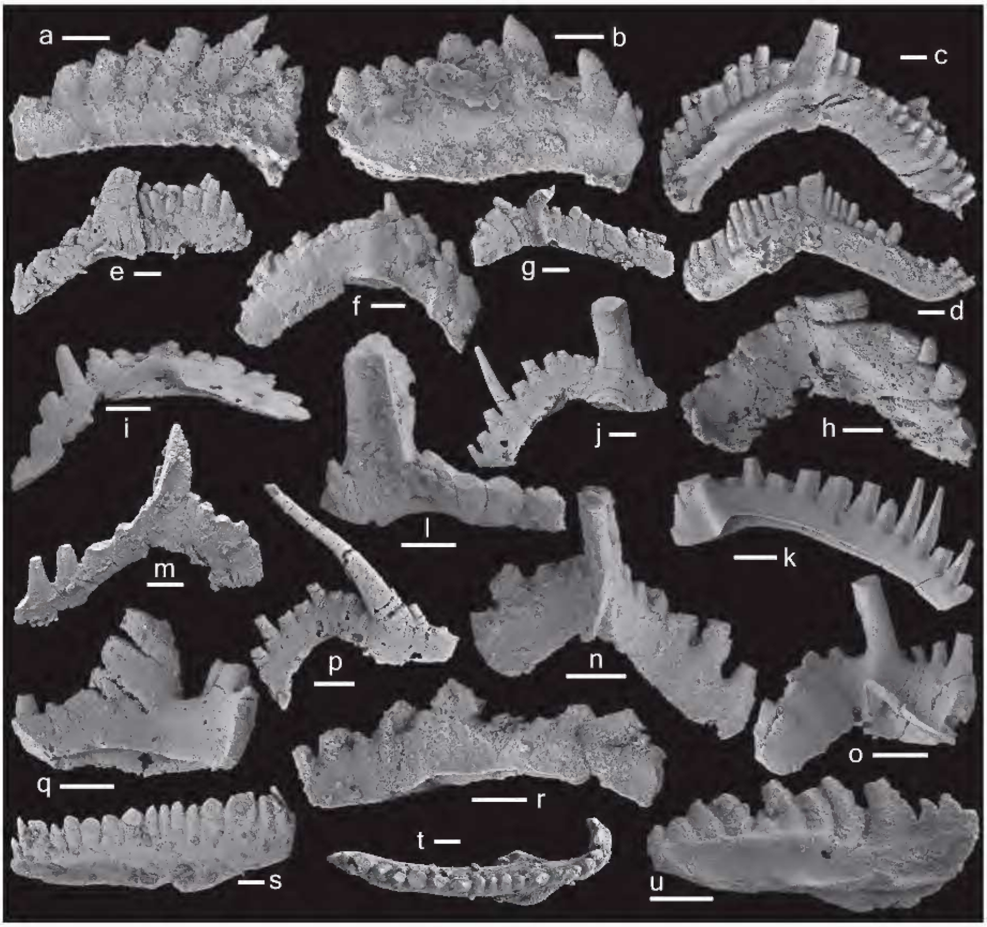

Figure 5. **a-i, k-n, p-u, *Wurmiella excavata* (Branson and Mehl, 1933); a-b, Pa element; a, MMMC5102, outer-lateral view (IY276-001); b, MMMC5103, inner-lateral view (IY276-002); c-i, Pb element; c, MMMC5104, inner-lateral view (IY249-008); d, MMMC5105, outer-lateral view (IY249-011); e, MMMC5106, inner-lateral view (IY249-013); f, MMMC5107, outer-lateral view (IY276-004); g, MMMC5108, inner-lateral view (IY249-020); h, MMMC5109, inner-lateral view (IY276-003); i, MMMC5110, basal view (IY276-009); k, M element, MMMC5111, posterior view (IY277-003); l-m, Sa element; l, MMMC5112, anterior view (IY276-010); m, MMMC5113, upper-anterior view (IY249-006); n, Sb element; MMMC5114, posterior view (IY276-006); p-r, Sc element, p, MMMC5115, antero-inner-lateral view (IY249-019); q, MMMC5116, inner-lateral view (IY276-008); r, MMMC5117, inner-lateral view (IY276-011); s-u, Pa element, s-t, MMMC5118; s, outer-lateral view (IY249-023), t, upper view (IY249-009); u, MMMC5119, inner-lateral view (IY276-024); all from sample C1985 (allochthonous limestone block possibly within the Kerrawary Siltstone), except for k, from sample C1858 (Hawkins Volcanics). j, o, *Kockelella* sp. C; j, M element, MMMC5120, posterior view (IY249-017); o, Sb element, MMMC5121, posterior view (IY276-007); all from sample C1985 (allochthonous limestone block possibly within the Kerrawary Siltstone). Scale bar 100 µm.**

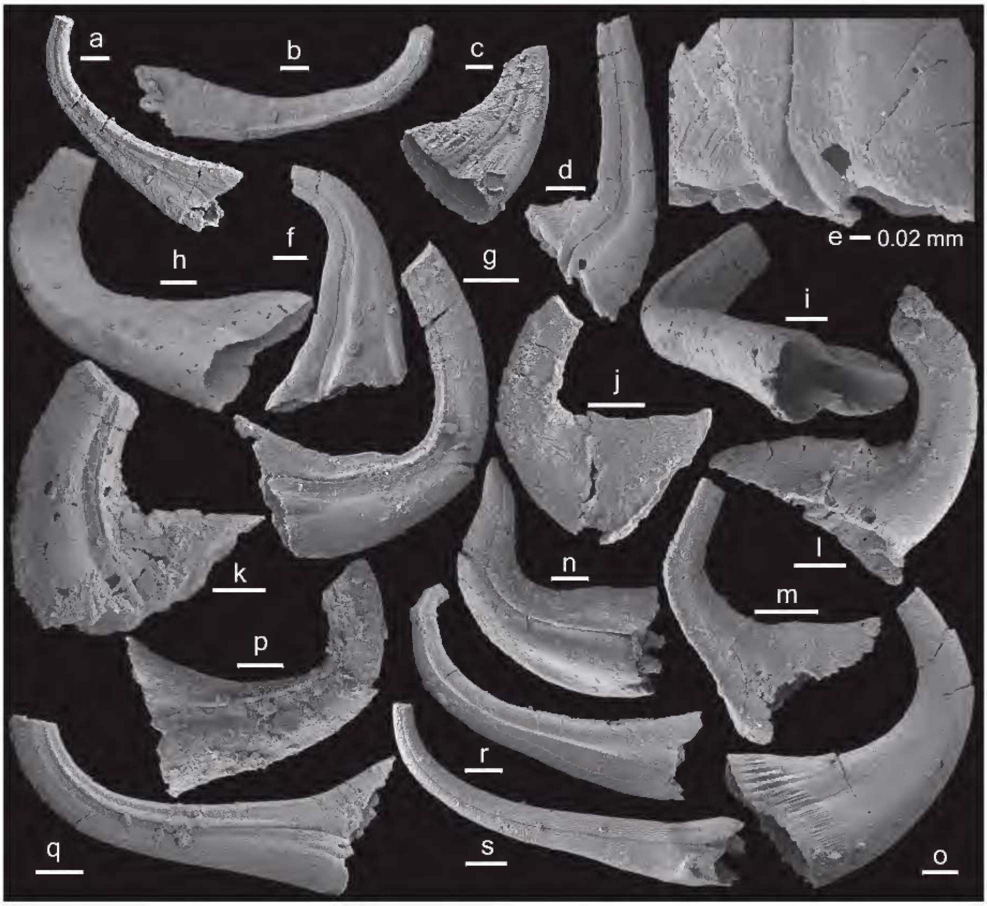

Figure 6. a-s, *Panderodus* sp. nov.; a, from sample C1862 (Hawkins Volcanics), Sd element, MMMC5126, outer-lateral view (IY249-003); b-c, Sd element, b, MMMC5145, inner-lateral view (IY277-009); c, MMMC5127, outer-lateral view (IY249-022); d-e, Pb element, MMMC5131, d, outer-lateral view (IY277-004), e, outer-lateral view, close up showing basal wrinkles and panderodid furrow (IY277-005); f-g, Sb element; f, MMMC5132, outer-lateral view (IY277-007); g, MMMC5133, outer-lateral view (IY277-006); h-i, Sd element, MMMC5134, h, inner-lateral view (IY277-013), i, antero-basal view (IY277-012); j, m, Sc element; j, MMMC5135, inner-lateral view (IY277-022); m, MMMC5136, inner-lateral view (IY277-026); k-l, Pa element; k, MMMC5137, outer-lateral view (IY277-024); l, MMMC5138, inner-lateral view (IY277-025); n-p, Sb element; n, MMMC5139, outer-lateral view (IY277-010); o, MMMC5140, inner-lateral view (IY277-011); p, MMMC5141, lateral view (IY277-015); q-s, Sd element; q, MMMC5142, outer-lateral view (IY277-020); r, MMMC5143, inner-lateral view (IY277-018); s, MMMC5144, outer-lateral view (IY277-017). All specimens (except for a) from sample C1985 (allochthonous limestone block possibly within the Kerrawary Siltstone). Scale bar 100 µm unless otherwise indicated.

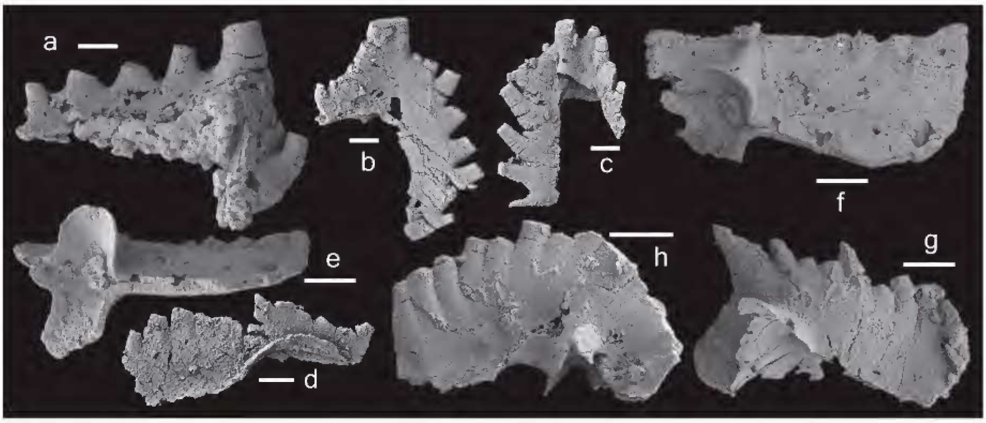

Figure 7. a-c, *Kockelella* sp. B; a, Pa element; MMMC5128, posterior view (IY276-015); b-c, Sb element; b, MMMC5129, anterior view (IY249-014); c, MMMC5130, posterior view (IY249-016). d-h, *Ozarkodina* sp.; from sample C1985 (allochthonous limestone block possibly within the Kerrawary Siltstone); d-f, Pa element; d, MMMC5122, inner-lateral view (IY249-010); e-f, MMMC5123, e, basal view (IY277-001), f, inner-lateral view (IY277-002); g-h, Pb element; g, MMMC5124, outer-lateral view (IY276-022); h, MMMC5125, inner-lateral view (IY276-023). Scale bar 100 µm.